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1. 1913. Russian Thistles. South Dakota Farm Page, Western Newspaper Union, No 28, January 2, 1913 [Dec. 23, '12] Farm page, articles not included except in these cases
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Title-page of first printed
botanical article. G. R. Bisby.

Russian Thistles

By Guy Bisbey, Assistant in Botany, South Dakota State College, Brookings.



Russian thistle. (a) Branch of mature plant, natural size. (b) Young seedling. (c) Flower and hairs. (d) Flower. (c and d) enlarged three times. (e) Seed enlarged five times. (f) Embryo. Cut used by permission U. S. Dept. of Agriculture.

Fifteen or twenty years ago South Dakota and neighboring states were up in arms against the Russian thistle; laws were passed against it and everyone was alarmed lest it would take the state as it had already taken large tracts in the dry regions of Russia. It is of special interest to South Dakota people to recall a little of the history of this weed.

In 1872 not a Russian thistle was known to grow in North America, although it was a troublesome weed in Russia, where it was called "Leap the Fields" or "Wind Witch." Then about 1873 or 1874 it was introduced near Scotland, South Dakota, in some flax seed imported from Russia. It took the plants a few years to get started, but by 1877 they had appeared in Yankton county, and by 1888 had infested most of the counties in South Dakota between the James and Missouri rivers, south of Huron and Pierre. Winds and a dry year then extended the weed north into North Dakota, and stock cars and other carriers of seed soon carried it here and through all the surrounding states. People were all worried in the 90's, and it certainly did cause an enormous amount of damage those dry years. It is still so common that almost everyone knows it; but the wetter years after 1900, coupled with warfare against it, served to make the plant scarcer. The last few years we have had a number of inquiries about it, the weed being especially abundant last year (1911), and in some localities west of the river it has been stacked as hay this year.

The question is often raised as to whether or not the Russian thistle, which is not really a thistle, but belongs to the same family as the beet, has any food value. Chemical analysis shows that it contains considerable nutriment, although it has quite an amount of indigestible fibre. Whenever stock can and will eat the plant, they do fairly well on it. Russian thistles are of course annuals, that is, they grow up from seed each year, and it takes them quite a while to get a start, longer than grasses and other plants that have roots already alive and ready to send up shoots at the opening of spring, it being usually the latter part of May before the "this-

ties" are up large enough for stock to get a bite at them. In all but the extremely dry parts of the state, forage is the most abundant at the time they are up and edible, so that if anything else will grow, the weed is useless as food. However, since the Russian thistle rapidly sends a long tap root down into the ground, it can obtain moisture where other plants cannot, and having the advantage of not being crowded by other plants, there is, in dry regions, sometimes quite a crop of Russian thistles, and scarcely anything else. Sheep and cattle will eat the plants quite readily, better than horses or hogs will. In the dry parts of South Dakota, then, they may be put to considerable use as feed for stock, especially during the time the thistles are young and soft. They become thorny in about six weeks from the time they are up large enough for stock to eat, that is, about the middle of July, and then ripen their seeds in August or September; the roots rot off at the surface of the ground, and the weeds blow about, and scatter their seeds as they go.

Russian thistles, though not as troublesome as they once were, are still quite a pest in many parts of South Dakota, while on the other hand, they are of some value as forage in the drier parts of the state. The problem of killing them is certainly not as hard as the killing of Canada thistle or quack grass, as Russian thistles must grow from the seed each year, and it has been shown that if they are cut off near the surface of the ground, the root will not grow another plant. The weed is more troublesome than the Canada thistle, however, from the standpoint of numbers. It is somewhat of a pest in grain fields, but where it can be cut down with a mower, or cut off with a cultivator, it can be quite easily killed. The worst difficulty is that no matter if you are careful to kill all your own plants, your careless neighbor's thistles will tumble across your land, scattering the seeds. However, a good fence will stop most of them, and if they can be burned off the fields, the seeds will be largely destroyed.

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NO. 8

SOME OBSERVATIONS ON THE FORMATION OF THE
CAPILLITIUM AND THE DEVELOPMENT OF
PHYSARELLA MIRABILIS PECK AND
STEMONITIS FUSCA ROTH

BY GUY R. BISBY

BROOKLYN, N. Y.

1914

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First scientific paper. G. R. B.

SOME OBSERVATIONS ON THE FORMATION OF THE
CAPILLITIUM AND THE DEVELOPMENT OF
PHYSARELLA MIRABILIS PECK AND
STEMONITIS FUSCA ROTH¹

G. R. BISBY

WITH PLATE XXIV

While examining preparations of *Physarella mirabilis* with a view to a study of nuclear phenomena, certain observations were made on the development of the capillitial threads so numerous in this species. In view of the fact that *Physarella* has not heretofore been studied cytologically; and, further, since the formation of the so-called solid capillitium is still a matter of discussion, it seems worth while to publish at this time the results so far obtained. While the study was in progress, some fruiting specimens of *Stemonitis fusca* were secured, from which supplementary data were obtained.

The literature pertaining to the capillitia of Myxomycetes has been carefully summed up by Harper ('00, '14*b*) and by Harper and Dodge ('14*a*), so that it is unnecessary to give here more than a brief glance at earlier investigations. Harper, in his papers on the subject, has described thoroughly the formation of capillitium in certain species in which it is distinctly hollow, and was able to corroborate and add much to Strasburger's ('84) earlier account of the process of formation. In his paper on cleavage in a recent issue of this Journal, Harper gives incidentally some data regarding the capillitium of *Didymium melanospermum*, but does not dwell upon the methods of its formation.

MATERIALS AND METHODS

Pieces of well rotted wood were collected in Prospect Park, Brooklyn, in November, 1913, and placed in covered battery jars. Upon this wood developed several species of Myxomycetes, the plasmodia of *Physarella* being especially abundant. Sporangia in large numbers were formed repeatedly, yet sufficient vegetative plasmodia usually

¹ Brooklyn Botanic Garden Contributions, No. 8.

remained to continue the culture. These developing sporangia were fixed in various stages of development in the Flemming-Strasburger medium solution, and stained principally with Flemming's triple stain.

The development of sporangia in cultures usually began during the afternoon and was completed by the following morning. Some little variation was observed as to the hour of maturity of certain fruiting groups, due possibly to somewhat unusual conditions of light, heat, or moisture. It was curious, however, to note that the various forming sporangia of a group developed almost simultaneously, in spite of the fact that all connection between them was early lost, and that some were at the edge of the water in the bottom of the jar, while others were formed on higher and apparently much drier portions of the wood. Mature sporangia were, however, perfectly normal in any case.

CAPILLITIUM FORMATION IN *PHYSARELLA MIRABILIS*

A mature sporangium (see figure 15) in this species contains a large number of more or less branched capillitial threads radially arranged. These threads are smooth, except for an occasional small spinous projection, and at first glance appear solid, except where they broaden out to constitute a lime knot. These knots are numerous, and vary in size from that of a barely perceptible swelling in a capillitial thread, to large spicules extending from side to side of the sporangium.

When the plasmodium first begins to form lumps where sporangia are to occur, the protoplasm presents no essentially different appearance from that of the vegetative stage, save that much of the extraneous substances has been extruded and left along the somewhat slimy trail; the same bubbly appearance is presented. Before long, however, spaces appear in the protoplasm, into which waste substances, largely lime granules, are excreted. In sections of the protoplasm as it becomes more finely granular, fine tubes can be detected, sometimes connecting the knot spaces with the exterior, and sometimes without any perceptible attachment to a developing lime knot. The membrane surrounding the tubular opening is continuous with the membrane surrounding a knot space, if any of the latter be in connection with this opening.

Such a condition is shown in figure 1; the lime knot and capillary tubules connected with it are bounded only by a plasma membrane continuous with the membrane at the external surface of the proto-

plasm. In this figure the protoplasm has shrunken slightly away from the sporangium wall. This shrinkage is undoubtedly artificial. The lime knot is nearly filled with cystolithic granules of calcium carbonate; in this instance, the acids of the fixative apparently did not penetrate sufficiently to dissolve out the lime. In the figures following (figures 2-4, II) representing succeeding stages, the calcium carbonate appears to have been largely removed and only a small amount of substance remains in the lime knots. In young stages, the tubular spaces which extend through the protoplasm and which define the location of future capillitial threads, usually appear empty and are rendered visible only by very careful focusing. They are usually of a very narrow diameter; most of the mature threads, for that matter, are also much attenuated. The capillitial space in the center of figure 1 is, however, slightly wider than usual and contains some stainable substance, possibly lime. The sporangial wall in this and certain other figures presents an altered appearance due to the removal of the lime naturally present. Two aggregations are shown, however, in the wall of figure 1 which are interpreted as areas in which lime has been present.

Figure 2 represents a somewhat later stage of capillitium formation. The protoplasm is seen to be in contact with the forming thread, a plasma membrane being evident only where the lime knot, from which the contents have been largely dissolved, has shrunken away. The sporangial wall in this figure is rather thick, and its inner surface is in direct continuity with the walls of the thread, while the thread itself is in turn continuous with the walls of the lime knot. This capillitial thread in figure 2 is clearly hollow save for an attenuated portion near the periphery of the sporangium, where no lumen is evident.

The threads are by no means all formed simultaneously. Spaces without deposition may be found in sections showing capillitial threads which are nearly mature.

Figure 3 shows similarly the continuity of the thickened walls of the lime knot and those of the threads. In this case a more advanced stage is figured, for the bounding walls are much thicker than in the previous figure. Shrinkage of the lime knot has not occurred, although its contents have been largely removed.

In figure 4 the hollowness of the narrow thread is not apparent. Here is shown further the connection of the capillitial threads and the

lime knots, as well as a branching thread. Figure 5, from an older sporangium, shows again the connection of thread and exterior. The hollow nature of the thread is here again plainly apparent where it widens out slightly. In this figure the protoplasm appears not at all shrunken, being in intimate contact with both capillitial thread and sporangial wall.

Figure 6 represents a small section of material collected in the morning shortly before the time of complete maturity of the sporangia. In some sporangia of the collection at this hour, cleavage had progressed to a considerable extent; while in the majority of cases cleavage is not so evident, the protoplasm being still in close contact with the thread, in the manner shown in the figure. Figure 7 does indeed indicate a case at this stage in which there is a slight space between the thread and the plasma membrane, and similar cases may in fact be found at other stages. I have interpreted such cases, when occurring at some time prior to cleavage, as arising from a slight shrinkage of the protoplasm away from the threads, due probably to fixation. At any rate, this earlier shrinkage should be clearly distinguished from the normal cleavage furrows which later follow the capillitial threads and which have been interpreted below as normal occurrences. The nuclei present an interesting appearance at this stage for, as is shown by one in figure 6, many are surrounded by a vacuole-like space. Harper points out ('14*b*, p. 133) this same phenomenon in *Didymium*; and interprets it as "hardly due to shrinkage in fixation, since they are scattered among other nuclei which show no such peculiarity."

CAPILLITIUM IN RELATION TO CLEAVAGE IN *PHYSARELLA*

Although the threads may be found in contact with the cytoplasm until a short time prior to cleavage, at the first suggestion of that phenomenon there is no doubt but that this contact ceases to exist. Harper has elaborated this point in his *Didymium* paper. Figure 8 shows an early stage of cleavage, in which every forming furrow is plainly associated with one or more capillitial threads, which appear in cross or oblique section in the preparation. The threads all appear to be hollow; that this appearance is not an artifact is attested by numerous observations on other material. At the upper right in figure 8 is a thread which has not yet been surrounded by a cleavage furrow. However, a slight space, as is commonly found at this stage, surrounds the thread. Conditions in the left part of figure 8 portray

a slightly more advanced state in that the cleavage furrows are of a greater diameter. Near the center of this figure cleavage has not actually been instituted, but the cytoplasm presents a more hyaline appearance, suggesting very clearly that cleavage in this place is about to result.

In figure 9 is represented a stage of cleavage slightly more advanced, in which the nuclei are in the equatorial plate stage of division, and each is surrounded by a hyaline space. The longitudinal view of the thread in this figure shows plainly its hollow nature. The manner in which cleavage furrows follow the threads is suggested by this figure, although it is difficult to picture the irregular fissures passing as they do at right angles to the axes of the capillitial threads, as well as up and down them.

Figure 10 shows a still later stage in cleavage. The large piece of spore-plasm shown in the figure is bounded here and there by capillitial threads in close proximity. Many of the threads lie, in fact, in bays or deep indentations of the protoplasmic mass, suggesting their intimate association with the inauguration of the cleavage furrows. A shrunken lime knot is represented in cross-section at the upper left part of the figure.

Figure 11, from a nearly mature sporangium, shows again the continuity of the inner portion of the sporangial wall and the exterior boundary of a larger lime knot, cut somewhat diagonally. The lime contents of both knot and wall have been largely removed by the action of the fixative.

Figure 12 was drawn from a mature sporangium crushed in a drop of water on the slide. It shows a mature thread, plainly hollow and not solid, as might be supposed from a hasty examination, of somewhat varying diameter, and two lime knots, the larger of which is small compared with the size of an average knot. A spore is shown adjacent for comparison of size. Within the knot, as is in fact always the case in *Physarella*, are many granules of calcium carbonate, rather uniform in size and shape. When these are dissolved in acetic acid, the knot presents the same essential appearance as it does in sections of fixed material.

Figure 13 represents a mature capillitial thread. As is shown, branching occurs; while the surface is smooth save for the "spines" occasionally present. This thread is hollow, as is represented in the figure, but this condition is by no means clearly apparent in every

mature capillitial thread. Chloroiodide of zinc solution, with which they stain yellow, often serves to bring out more clearly the hollowness of these threads.

Figure 14 is another preparation from a mature sporangium, the figure being a surface view of a portion of the sporangial wall. A small but definite area is shown densely charged with lime granules, while in the surrounding wall are embedded more or less isolated lime granules. The larger lime knot undoubtedly corresponds to the knots shown in section in figures 1 and 11. The darker spots in figure 14 represent aggregations of yellow coloring matter. It may be noted here that the plasmodia of *Physarella mirabilis* are bright yellow; the hollow stalk of the mature sporangium is reddish; while the spore bearing portions are, to the naked eye, grayish-yellow. Each lime granule in a knot or in the sporangial wall has also a yellowish tinge, and this color seems to dissolve out in water, leaving the granules nearly colorless after a time. The capillitial threads also have a yellowish cast when viewed under the microscope.

Figure 15 is a partially diagrammatic drawing of three-fourths of one of the mature, somewhat funnel-formed sporangia, on its hollow, cylindrical stalk, showing the relation of the various parts.

THE CAPILLITIUM OF *STEMONITIS FUSCA*

While the work on *Physarella* was in progress, fruiting material of *Stemonitis fusca* was collected from one of the cultures. It was not long after the emergence of the white plasmodium from the interior of the wood, that a heaping up of the protoplasm occurred, defining the sporangial groups. Complete development from the first appearance until maturity occupied only the twelve hours from noon to midnight. About two hours after the sporangia in the fruiting groups had attained their typical size and shape, the brown tint of maturity was apparent.

The classical example of the so-called solid capillitium is that of *Stemonitis*. The arrangement of the intricate system of capillitial threads in this species is a familiar picture. The hollow stalk continues as a central columella to the very summit of the sporangium. From this columella branches off at right angles a profuse system of rather coarse, branching threads, which terminate sub-peripherally just within the fragile, often evanescent sporangial wall in a delicate, anastomosing, capillitial sac.

In longitudinal sections of very young stages, the hollow stalk is seen extending as a comparatively large, cylindrical cavity from the very base of the fruit body up to near its summit. The plasma membrane surrounding this central cavity secretes the hollow stalk up which the protoplasm climbs to form finally the sporangium along its upper portion. Figure 16 shows in median section the upper portion of such a central axis, cut somewhat obliquely. At its very apex, the irregular and rather tubular space in which the columella is formed appears broader than it is below, where deposition of wall substance has begun. In the lower part of figure 16 the somewhat shrunken and diagonally cut columella has attained some degree of thickness from deposition of wall substance from the plasma membrane. Into the upper portion of this space may be noted the intrusion of finger-like processes of protoplasm, while some irregular masses of protoplasm lie detached within the cavity itself. Indeed, one quite commonly notes in sections the presence of protoplasmic masses inside the columellar cavity, even in much older stages. The figure illustrates quite clearly just how their presence in such situations is to be explained, arising as they do from fragments detached from above by the ever advancing columellar apex. This point will be considered in some detail in the general discussion which follows.

Just above the apex of the cavity in which the stalk is being formed is seen the much vacuolated protoplasm which marks the region into which the columella is soon to advance. Denser areas lie still further beyond; while still other dense areas are shown at the sides of the upper portion of the space. Extending upward at a slight angle from the rising columellar cavity may be noted a tubular space. Careful focusing at this part of the preparation reveals in fact a profusion of such narrow spaces, radiating in an upward direction from the apex of the large cavity and extending in some cases even to the periphery of the mass of protoplasm. Occasionally it can be seen that such tubular spaces are directly connected with the main large columellar cavity, the plasma membrane of the one being continuous with that of the other.

Forming capillitial threads may be noted in quite an early stage of the sporangium. Not, however, until the structure had assumed its final form, in the fruiting material studied, were the capillitial threads observed in any abundance. The method of deposit of capillitium in *Stemonitis fusca* appears to be in entire agreement with the process

as found in *Physarella*. Figure 17 shows an early stage in which the tubular space in the still foamy protoplasm is bounded only by a thin membrane, no wall deposit being as yet apparent. I have not attempted to show in great detail the various degrees of thickening of these developing threads, instances of which are rather common in the preparations. Figures 18, 19 and 20 show this phenomenon incidentally, and perhaps as convincingly as a more detailed series of drawings would.

Figure 18 represents the attachment of a capillitial thread to the columella. The thread has here attained some thickness, as may be observed further away from the central columella where the thread widens somewhat. At this wider portion the wall appears somewhat wrinkled or irregular. Near the columella the thread is of sufficient degree of attenuation to obscure the lumen. The protoplasm in this instance is in close contact with the thread. The expanded attachment of the capillitial thread to the columella is of some interest, since it is evident that the broader attachment is a continuation of the outer portion of the thickened central columella. So far as my own observations have gone, I have not found the lumen of the columella to be continuous with the lumen of the capillitial thread, which point is in agreement with De Bary's findings.

Figure 19 shows a cross section of material in a similar condition; here, however, the protoplasm has been shrunken away from the thread and half the columella, possibly by the initiation of cleavage. Within the columella may be noted the presence of some stainable substance, probably protoplasm.

Figure 20 represents a case in which cleavage is just beginning from the surface of the sporangium. The nuclei are in the equatorial plate stage, and the protoplasm is distinctly more finely granular and richly stainable at the periphery, perhaps due, as Harper suggests, to contraction of sporeplasm and extrusion of water. As is shown in the figure, the reticulations that form the net-like capillitial sac of the mature sporangium have been already formed just within the outermost portions of the protoplasm. Deeper down within the more foamy protoplasm the threads are still, in some cases, clearly in contact with the cytoplasm. In most cases in this preparation it was clearly evident that the threads are of a hollow nature. Although any relation to cleavage is not definitely shown in this figure, it is apparent from a study of the sections that here also the cleavage furrows are

influenced and defined to a considerable degree by the capillitial threads, just as in *Physarella*.

As is well known, the sporangial wall in *Stemonitis* is very fragile and eventually disappears. In younger stages it may be noted as a thin bounding membrane; while from older or mature sporangia it is usually missing. In figure 21, from a preparation similar to the one from which figure 20 was drawn, this outer wall is shown, broken and removed from contact with the protoplasm. A very delicate, connecting capillitial thread is to be seen in figure 21, its attachment to the sporangial wall quite comparable to that already examined in *Physarella*.

Figure 22 is a high power drawing of a mesh of the inner portion of the mature dried capillitium. As is indicated by the dotted line, a portion is clearly hollow; while other parts, due to their dark color and narrow diameter, did not present an appearance that could render possible a statement that they were hollow. Of course an appearance simulating hollowness can easily be obtained if a thread is slightly out of focus. There is, however, no doubt but that, though the lumen may be at times extremely capillary, the most of these threads are really hollow; a focus on a bent "knee" of an anastomosing thread, for example, often clearly demonstrates this point.

GENERAL DISCUSSION

The term "vacuoles," as applying to the openings in which the capillitial threads are to develop, would seem to be misleading in the case of the two species under discussion, since these openings in question appear to be quite commonly, if not indeed invariably, invaginations from the sporangial surface, or from the plasma membrane bounding the columella. It is of course quite likely that these more or less tubular openings in the protoplasm are due to some tensions arising in the viscid mass; the fundamental causes resulting in this and related phenomena are, however, obscure. Much easier to understand, it seems to the writer, is the process of deposition of the fine, smooth capillitial threads.

Taking first the case of *Physarella mirabilis*, tubular capillary spaces appear in early stages of sporangial development. These spaces are no doubt filled at their beginning with watery sap and aqueous waste, connected as they are with lime-knot spaces and opening upon the developing outer membrane. From the plasma

membrane surrounding these capillitial primordia, wall substances are next secreted. I am as yet unable to state positively whether the thin wall deposited early in capillitium formation is folded or actually pushed inward by subsequent external deposits from the surrounding plasma membrane; or whether the tubular cavity gradually increases in size, deposition thus resulting in a constantly increased total diameter of the capillitial threads. I am inclined to think that the former process obtains to a certain extent and that actual diminution in size of the lumen of the capillary tubules sometimes consequently results. The substance secreted to form the walls of these hollow threads is presumably plastic for some little time after formation. Furthermore, there may undoubtedly occur a wrinkling or folding of the thread during the process of drying, particularly in regions where it is comparatively broad. This latter appearance is more frequent in *Stemonitis fusca*. However, in any case, as has been previously stated, there can very frequently be observed within the thread a lumen of greater or lesser diameter. I know of no good reason why practical solidity should not occur in certain cases; such, for example, as would result from a deposit in a tubular space of extremely capillary proportions.

It is further shown beyond doubt in the case of *Physarella* the same method of deposit obtains in the formation of walls about both lime knots and capillitial threads, as that seen in the formation of the inner part at least of the sporangial wall. The first few figures show clearly the continuity of the boundary of those parts. Although the external surface of the outer peridium appears thicker, presumably from hardening through exposure to the air, I have no doubt but that the whole sporangial wall is of similar character and deposited by protoplasmic secretion.

The large amount of lime in the mature sporangium of *Physarella* suggests an approach to the condition obtaining in *Fuligo varians* in regard to the amount of lime present. The old analysis of Reinke and Rodewald ('81) credits that species of *Fuligo* with 27.7 per cent of calcium carbonate, and 5.33 per cent of calcium in combination with higher fatty acids. The absorption, deposition, etc., of this calcium carbonate in these Myxomycetes furnishes an interesting problem, since, as is well known, CaCO_3 is soluble only in 100,000 times its own weight of pure water. It is further curious that some species should provide themselves with such large quantities of calcium carbonate, while others apparently lack it entirely.

The formation of the columella in *Stemonitis fusca* takes place by means of a progressive deposition of wall material along a cylindrical space that reaches from the base of the young fructification upward through the rising mass of protoplasm. The irregular radiations and extensions of the apical part of this space resembles somewhat the condition as figured by De Bary ('87) for *Stemonitis ferruginea* (p. 432, figure 186, a) in which the upper portion of the columella is pictured as frayed out in a brush-like fashion. The exceedingly vacuolar appearance of the protoplasm above the columellar space (see figure 16) suggests both the rapid pushing up of slender, tubular invaginations from the apex of the space itself, as well as the final incorporation into the columellar space of the vacuoles that lie in its upward path.

It has already been pointed out that some protoplasm is regularly left within the columellar space, cut off from the mass above the columella by the upward pushing, slender invaginations and vacuolar cavities which are characteristic of this area apically from the tube. In younger stages of columella formation, the protoplasm included in its hollow interior shows some evidences of continued activity, although often broken up into very small, rounded fragments. In older stages, however, its appearance suggests a much less active condition; and it probably ultimately dies.

In *Stemonitis* the same essential phenomena in regard to capillium formation undoubtedly obtain as those described above for *Physarella*. Views of early stages of the spaces in which are to be secreted the capillitial threads show an appearance of considerable irregularity and anastomosis, and they are with difficulty traced through the foamy protoplasm (figure 17). Later stages show the threads with more or less thickening deposited adjacent to the plasma membrane. Ordinarily, careful focusing on thin sections reveals clearly the tubular character of these threads. The attachment of capillitial threads to the central columella displays a condition somewhat comparable to the attachment to the sporangium wall in the case of *Physarella*. It is noteworthy in *Stemonitis* that the threads are evidently in connection with the exterior deposition upon the columella, pointing to the fact that the threads are formed by a deposition no different from that which forms the columella; nor indeed from the wall deposit itself, as figure 21 evidences. The further fact that in the cases figured (figures 18 and 19), the lumen of the thread is not continuous with the lumen of the hollow columella shows that in these instances at least,

the capillitial cavities were started to be formed some time after the columella wall deposit had attained some degree of thickness. If the capillitial tubules should begin to form as early as columella deposit, the lumen of the two should undoubtedly be continuous.

The formation of the reticulated, capillitial sac just within the exterior protoplasm of *Stemonitis* is at first glance a puzzling phenomenon. This would obviously result in a layer of spores being formed outside the main capillitial network; in fact, a careful examination of a fresh, mature sporangium shows that such is indeed the case. It is evident that this rich development of a layer of capillitial threads just within the peripheral protoplasm must result from a very rapid secretion of wall substances from the rapidly maturing external protoplasm. Only comparatively few of the very delicate threads which connect this anastomosing network with the external wall apparently have an opportunity to form, so quick are these changes in the peripheral portion of the sporangium.

Contrasting the sporangial walls of the two species under discussion, it seems clear that the thickness of wall deposit must depend to some extent upon the length of time the peripheral protoplasm remains in a relatively quiescent state. In *Physarella*, external secretion apparently continues during a considerable portion of the time of development of the sporangia. In *Stemonitis*, on the other hand, cleavage begins at the exterior very shortly after the heaping protoplasm attains its final shape, and in consequence the sporangial wall reaches only a meager development.

Some mature capillitial threads in *Stemonitis fusca* are somewhat flattened; some are somewhat irregular in shape, especially at the meshes; some present a wrinkled or crumpled appearance, as before mentioned. In some cases the occurrence of solidity is hard to disprove; but studies of many sections and of mature capillitia indicate without any doubt that hollowness of the threads is in reality very common.

The smoothness of the exterior of the capillitial threads in both species studied is in striking contrast to the spirally thickened and otherwise marked, distinctly hollow threads of certain other Myxomycetes, such, for example, as *Trichia*. But in the essential features of the process, the phenomena connected with the formation of the two types of threads are regarded as entirely similar, consisting in both cases in the deposition of hollow threads by plasma membranes

lining tubular capillary spaces. In *Trichia*, however, the capillitial cavities are of relatively large diameter; while in the two species described in this paper, they are of very narrow diameter. The fact that in *Trichia* and similar cases, the capillitium starts in vacuoles in the interior of the protoplasm, while in *Stemonitis* and *Physarella* these spaces apparently originate as invaginations of the external plasma membrane or that lining the capillitial or columellar cavities, is undoubtedly of fundamental importance.

Cleavage in these two forms under consideration is decidedly progressive. This shows particularly strikingly in cross sections of young sporangia of *Stemonitis*, in which cleavage will often be seen to involve at one time only a small sector of the peripheral protoplasm. I am unable, however, to add anything new to the valuable observations made along these lines by Professor Harper ('00, '14b).

I am indebted to Dr. Olive, under whose supervision this work was carried on, for suggestions and criticisms freely given during the course of these investigations.

SUMMARY

1. The capillitium of *Physarella mirabilis* and of *Stemonitis fusca* is formed within tubular capillary spaces. In both cases these spaces are formed as invaginations into the protoplasm, and are not considered to be vacuoles. From the plasma membrane lining the tubular spaces occurs a progressive deposition of substance to form the walls of the capillitial threads. This deposit is continuous with that forming the sporangial wall; and, in *Stemonitis*, as well with that which forms the columella wall, to which the radiating, tubular threads are attached. In *Physarella*, a continuous wall also exists, bounding capillitial threads and lime knots, when they are in connection with each other.

2. The protoplasm remains in contact with the capillitial threads until a short time prior to cleavage. Cleavage furrows then appear, which follow the threads and which are thus determined to some extent by the capillitium.

3. The mature capillitial threads of these two forms are smooth (in *Physarella* an occasional spinous process occurs), and a careful examination shows that a majority of the threads are hollow and not solid as is usually stated. Where seeming solidity does occur, this is interpreted as due either to an actual collapse of the tube when in a plastic condition, or else in reality to the obscurity of the lumen owing to the fineness or opacity of the threads.

4. The columellar cavity in *Stemonitis fusca* pushes up from the base of the young fructification through the heaping protoplasm as a more or less cylindrical space. Progressive deposition of wall substance from the plasma membrane surrounding this space forms the resulting thick-walled, tubular columella.

5. The delicately anastomosing reticulations of the mature capillitial sac in *Stemonitis fusca* are formed subperipherally, just within a layer of peripheral protoplasm. In earlier stages, these reticulations are attached by a few fine capillitial threads to the fragile and evanescent sporangial wall.

BROOKLYN BOTANIC GARDEN, BROOKLYN, N. Y.

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EXPLANATION OF PLATE XXIV

The drawings, except figure 15, were made with the aid of the camera lucida, and drawn at the level of the stage. Zeiss compensating oculars 2, 6, 8 and 12 were used, together with Zeiss 2 mm. apochromatic objectives NA 1.30 and 1.40.

FIGURES 1-15, *Physarella mirabilis*.

FIG. 1. The early appearance of capillitial spaces, and a young lime knot. The sporangial wall, from which the protoplasm has somewhat shrunk, is already rather thick. $\times 750$.

FIG. 2. The capillitial thread, sporangial wall, and lime knot all have a common continuous boundary, which has in this instance attained an appreciable thickness. Shrinkage has occurred from the wall bounding the lime knot. $\times 1,000$.

FIG. 3. A somewhat later stage, with still thicker wall about capillitium and lime knot. $\times 1,500$.

FIG. 4. A preparation similar to figures 2 and 3, but showing shrunken lime knot and branching capillitial thread. $\times 1,000$.

FIG. 5. A capillitial thread and sporangial wall again showing continuity of bounding membranes. $\times 1,500$.



FIG. 6. Almost mature capillitial threads in which the lumen is not evident. $\times 1,000$.

FIG. 7. A stage approaching maturity, in which a space is shown surrounding the capillitial thread. $\times 1,000$.

FIG. 8. The cleavage furrows are limited by the capillitial threads, which appear in cross-section in the preparation, or else are cut somewhat obliquely. $\times 1,000$.

FIG. 9. A preparation taken from a similar stage, showing a cleavage furrow following in part the hollow capillitial thread. $\times 1,000$.

FIG. 10. Another similar, but somewhat older, stage of cleavage. $\times 1,000$.

FIG. 11. Showing the attachment of the sporangial wall and a lime knot. $\times 750$.

FIG. 12. A mature capillitial thread, containing two small lime knots; and a spore shown for comparison. From a mature, crushed sporangium. $\times 750$.

FIG. 13. Another capillitial thread, showing branching and the occasional spine-like projections. $\times 1,000$.

FIG. 14. Surface view of a portion of the wall of the sporangium, showing a large lime knot, small lime granules, and the yellow (shown as darker) pigment granules. $\times 1,000$.

FIG. 15. Diagrammatic drawing of a mature sporangium, showing expanded base, hollow stalk, funnel-shaped sporangium, sporangial wall, and the radially arranged capillitium and lime knots. \times about 20.

FIGURES 16-21, *Stemonitis fusca*.

FIG. 16. Upper portion of the space in which the columella is to be formed; showing thin columellar wall, protoplasmic inclusions, and the vacuolated area in the path of the rising axial cavity. $\times 250$.

FIG. 17. Young stage in capillitium formation; showing a space in which no perceptible deposit of wall substance has as yet been made. $\times 1,000$.

FIG. 18. Late stage in the development of the capillitium, showing attachment to the columella. $\times 750$.

FIG. 19. Similar condition to figure 18, but showing columella in cross-section. $\times 750$.

FIG. 20. A preparation from the peripheral portion of a sporangium, showing cleavage begun; together with a small fragment of the delicate, subperipheral, anastomosing, capillitial sac. $\times 750$.

FIG. 21. A portion of the fragile, evanescent sporangial wall, showing a small capillitial thread attached. $\times 1,500$.

FIG. 22. Small portion of capillitium, from a mature sporangium, showing anastomosis, and the hollow character of one thread. $\times 1,500$.

THE BROOKLYN INSTITUTE OF ARTS AND SCIENCES
BROOKLYN BOTANIC GARDEN

CONTRIBUTIONS

This series consists of papers originally published in botanical or other periodicals, re-issued as "separates" without change of paging, and numbered consecutively. It includes occasional papers, as well as those embodying the results of research done at the Brooklyn Botanic Garden, or by members of its staff and students. Twenty-five numbers constitute one volume. Offered in exchange, or for sale at 25 cents a number; \$5.00 a volume.

PRECEDING NUMBERS

1. *The educational work of botanic gardens.* 13 pages. 1911.
2. *The purpose of an introductory course of botany.* 8 pages. 1911.
3. *Cryptomeric inheritance in Onagra.* 11 pages, 2 figures, 2 plates. 1911.
4. *On the origin and present distribution of the pine-barrens of New Jersey.* 15 pages, 2 figures. 1912.
5. *Ingrowing sprouts of Solanum tuberosum.* 10 pages, 6 figures, 1 plate. 1912.
6. *Intermingling of perennial sporophytic and gametophytic generations in Puccinia Podophylli, P. obtogens and Uromyces Glycyrrhizae.* 15 pages, 1 plate. 1913.
7. *Studies of teratological phenomena in their relation to evolution and the problems of heredity. I. A study of certain floral abnormalities in Nicotiana and their bearing on theories of dominance.* 14 pages, 4 figures. 1914.

Say about Corey's Enohla

To Whom it May Concern

Having been present while the American Potato Corporation's fields were prepared for planting, and while the seed was selected, treated, cut and grown I am prepared to make the following statement regarding this year's crop:

The land is in excellent condition for potatoes, being clean, well prepared and well drained. The seed planted was very select, true to name and type; as an added precaution the fields were watched in order to rogue out any accidental mixtures. The seed was exceptionally free from disease and was thoroughly treated with formaldehyde solution before cutting. Incidental precautions, such as the disinfection of bins, barrels, etc., disinfection of knives and general care in cutting, were followed out. The fields were also watched so as to avoid diseases. This seed was carefully planted and thoroughly cared for as it grew, special care being used to secure effective spraying with Bordeaux Mixture.

The quality of the seed stock planted and the care exercised all along are showing results in healthy plants, and every indication points to a large yield of fine quality. Nothing has been left undone to have the crop free from disease and true to name.

Respectfully yours,

G. R. Bisby, Plant Pathologist.

Youngs Island, S. C., July 6, 1914

American Potato Corp.,

Presque Isle Maine,

Dear Sirs:

I obtained through Pat Wall Company one hundred barrels of Corey's Enohla seed potatoes which I planted on my farm, Youngs Island, South Carolina. These potatoes were planted very late owing to excessive rains at the time we usually plant our crop. We usually plant about the 10th of February but this year I finished with this seed on the 17th of March. From

Will eventually plant

Corey's Enohlas will

the first four and one half acres of this variety I dug an average of 68 barrels per acre; from the next ten acres I dug an average of 91 barrels per acre; and from the next two and one half acres, which I allowed to mature, I dug 110 barrels per acre. It is an early potato, not much, if any later than the Cobbler. You should strive to keep this seed absolutely pure for when any seed becomes mixed it is no good,

Yours truly,

C. M. Gibson

Sheldon, S. C., June 13, 1914

American Potato Corp.,

Presque Isle, Maine,

Dear Sirs:

Referring to Corey's Enohla seed potato bought of you this year, I desire to say that I planted them side by side with the Irish Cobbler, the only difference being in the time of planting: the Cobblers were planted one week earlier than the Enohlas, all conditions were equal. They were dug the same day and a sufficient test was made which showed that the Enohlas produced one third more per acre than the Cobblers. I am thoroughly convinced that the Enohla, under normal weather conditions, will produce more potatoes than any other variety grown in this section, and I paid for it great success.

Yours truly,

H. J. Rast,

Sheldon, S. C., April 29, 1914

American Potato Corp.,

Presque Isle, Maine,

Dear Sirs:

Replying to your letter of recent date I desire to say from the present outlook I do not think I shall want anything except Corey's Enohla seed potatoes for the coming season. I planted 350 bags of Spaulding Rose No. 4 which are very fine. They, like the Enohlas, are heavy bearers, and planted early to be dug late makes a good combination. I have an excellent crop of bugs as well as potatoes, and the vines are get-

75.
BROOKLYN BOTANIC GARDEN

LEAFLETS

THE BROOKLYN INSTITUTE OF ARTS AND SCIENCES

SERIES II

BROOKLYN, N. Y., OCTOBER 7, 1914

NUMBER 11

THE POTATO INDUSTRY OF NORTHERN MAINE AND ITS RELATION TO THAT OF LONG ISLAND

The potato industry of Long Island is becoming increasingly important, especially for the northeastern corner of the Island. From the point of view of food supply, it is clear that such agricultural interests as these are intimately bound up with the welfare of New York City. At first thought, however, it seems a far cry from the potato fields of northern Maine to those of Long Island and New Jersey. Yet, as will be made plain from the following account, the connection is in reality a close and vital one.

Northern Maine is widely known as a region where hunting and fishing are excellent; its woods, lakes, and streams, together with its cool climate, make it an ideal summer resort. The popular conception of Maine, with its "rock-bound coast" and densely forested interior, gives the impression that it is not an agricultural country. Aroostook County, in the extreme northern part of the State, although containing much natural forest and possessing a season too short for most crops, nevertheless is peculiarly adapted to one crop—the potato. For the past fifty years land has been gradually cleared and potatoes planted, until in 1913 the production in that one county alone was about twenty-five million bushels, twenty-two million bushels being shipped out, and about

three million bushels used within the county as table potatoes or converted into starch. For seed purposes especially, Aroostook potatoes are well and favorably known all through the eastern trucking sections, and are used for planting as far south as Florida and Texas.

The reasons for this prestige are not hard to find. The potato, naturally almost a shade plant, thrives in the cool climate of that country; the soil, a loose, well-drained loam, is particularly a potato soil; the rainfall is usually abundant. Being the main crop, thorough care is used in its production. And the superiority of northern grown, more immature, seed for planting further south has been repeatedly demonstrated. Aroostook County seed is especially valuable for this reason, and by railway and steamship is readily accessible to the trucking districts of the Atlantic States.

There can be no doubt but that the potato industry is not only of vital importance to northern Maine, where it has produced prosperity and wealth, but is likewise important to the whole eastern United States. This industry has been developing for some years, and in general has enjoyed a healthy growth. However, the very apparent simplicity of potato raising in northern Maine has resulted in some ill effects in the past; *e. g.*, the notion became prevalent that one could plant any sort of potatoes in Aroostook and harvest abundance. From sheer force of necessity, spraying to prevent late blight has been practiced for several years; but carelessness has been used in selection of the seed to be planted, as well as with regard to proper rotation of crops. Finally it resulted that diseases became very prevalent, not only in the tubers planted, but also in the soil itself, and varieties consequently began to "run out." It finally dawned upon some of the growers that, large though the yield was, it might be made larger, and the quality be made better.

The present is a time of awakening and endeavor to attain the maximum of quality and yield. A yield of three hundred bushels per acre has been common in the past; now and then a yield of five and six hundred bushels per acre was attained. This latter immense production of select, healthy potatoes is the goal toward which the wide-awake growers are now striving.

The primary cause resulting in this rejuvenation of the Aroostook potato industry was the discovery, in that county, of powdery scab, a serious, imported potato disease. This disease threatened to become disseminated throughout the whole country, so great is the distribution of northern Maine seed, some of which would, unless extreme care be exercised, undoubtedly be affected with this disease. Promptly upon its discovery, steps were taken by the State and Federal Departments of Agriculture to prevent shipment of tubers infected with powdery scab. The gospel of care and attention in the selection of the seed planted and shipped, preached first by plant pathologists, was taken up by wide-awake growers; adherence to this gospel was enforced by declaring a quarantine upon potatoes shipped, so that all had first to be inspected. While the eradication of this disease was being sought, other diseases were also brought to attention and avoided; varieties were cleaned up and freed from mixture with other varieties. The consensus of opinion now is that the discovery of this important disease in northern Maine was a blessing in disguise, and will result in much less potato disease there, as well as in better quality and better yield.

The Brooklyn Botanic Garden has been especially interested in this movement, particularly on account of the fact that one of the staff was temporarily released from Garden duties in order to take active part in the work. The writer, together with two other special students of potato diseases, accepted appointments for the season with some of the more progressive potato growers. The duties of these field workers were to keep close watch of all the details of selection, the proper methods of cutting, treating and planting of seed tubers; the control and final eradication of the diseases which appeared; the "roguing" for stray intruders in an otherwise pure variety; as well as the final harvesting, inspection and storage of the crop.

This year, practically for the first time, formaldehyde treatment of seed potatoes was practiced; many diseased plants have been removed from the fields, and the crop never looked cleaner and better. Thanks to the teaching of the plant pathologists and the enterprise of growers, northern Maine is still one of the most progressive and important potato raising sections of America.

The future of the potato industry in northern Maine may in general be prophesied as follows: the best seed the grower raises or can obtain will be planted on land that has been through the regular three year rotation of oats, clover, then potatoes. The fertilizer used will be the optimum of quantity in order to furnish sufficient plant food for the growth of a large crop. Diseases will be more intelligently watched for and avoided; and formaldehyde seed treatment, and spraying in the field will be thoroughly practiced. The various varieties will be freed from mixture and their type improved by selection and observation of growing plants. The yield will increase and the quality be better. Long Island, together with the whole Atlantic seaboard, will thus profit by the improved seed potatoes received from northern Maine.

G. R. B.

NOTICES

The Garden is open to the public daily, from 8 a. m. until sunset; on Sundays and holidays at 10 a. m. Conservatories open April 1-Oct. 1, 10 a. m.-4:30 p. m.; Oct. 1-April 1, 10 a. m.-4 p. m.

During the present season and until further notice, entrance to the Garden may be had only at the laboratory building on Washington Avenue, opposite Montgomery Street, on permission from the office. This temporary regulation is made necessary by extensive grading operations and the construction of new paths throughout the grounds.

The Garden may be reached by Flatbush Avenue trolley to Malbone Street; Franklin Avenue and Lorimer Street trolleys to Washington Avenue; St. John's Place trolley to Sterling Place; Ninth Avenue, Sixteenth Avenue, Union Street, Greenpoint and Smith Street trolleys to Prospect Park Plaza and Union Street, and Brighton Beach elevated to Consumers' Park Station. (The elevated train stops only when the conductor is notified in advance.)

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BROOKLYN BOTANIC GARDEN

LEAFLETS

THE BROOKLYN INSTITUTE OF ARTS AND SCIENCES

SERIES IV

BROOKLYN, N. Y., MAY 17, 1916.

No. 6.

POISON IVY

This plant, common in this region, and known scientifically as *Rhus Toxicodendron*, is the bane of a great many people who visit the country or the woods. There are few vacationists who, at one time or another, have not felt the effect of contact with poison ivy. But it is not even necessary to seek the country to find this plant; people in their walks about the city or even in the public parks may meet with poison ivy, for it is not an uncommon sight to find it growing in some waste yard or fence corner right in the heart of Brooklyn. It is truly a "snake in the grass," and anyone passing through an area of natural vegetation is liable, consciously or unconsciously, to touch the poison ivy.

Besides poison ivy, we have another member of the family, common in swamps, the poison sumach or poison dogwood (*Rhus Vernix*), which is even more poisonous to the touch.

Many people, especially Boy Scouts, with whom the knowledge is compulsory, and those who have experienced poisoning from it, have made themselves familiar with the appearance of poison ivy. There are, however, many people who are unfamiliar with this plant; it is not infrequently touched and otherwise handled in summer or autumn, for the plant possesses some beauty, especially when it has assumed autumnal coloration. Needless to say, poisoning usually results from such a procedure. It is not amiss here to describe briefly the appearance of the poison ivy plant.

The leaves are compound, composed of three ovate leaflets, thus being readily distinguished from the Virginia creeper, with five leaflets, with which poison ivy is often confused. Depending somewhat on the conditions, the plant grows as a trailing or climbing vine or else as a more or less erect shrub. The name

"Poison Oak" is often applied when the plant is shrubby. It scrambles over fences and walls; or in thickets and woods it climbs stumps and trees to considerable heights, clinging by means of tiny rootlets.

It is a well-known fact that individuals vary as to susceptibility to poisoning by this plant. There are those who claim immunity and who seem to be able to touch the leaves or stems with impunity. It is doubtful, however, that anyone can hope to allow this plant to touch him indiscriminately and always escape, for even those most "immune" are liable to be affected under certain circumstances; for example, if the plant touches more tender portions of the skin, or places where the skin is scratched or injured, especially if the parts touched are not washed with soap, or otherwise treated, soon after contact with the plant. Most people are especially susceptible when their skin is moist and perspiring. There are, on the other hand, those who suffer greatly from the slightest contact with poison ivy; those who feel its effects not only in a localized irritation and blistering of the skin where the plant touched it, but who suffer irritation or rash over a considerable area, or even, in extreme cases, over the whole body! And there are those who claim that they are affected even by proximity to a plant, or through passing by a fire where it is burning, without even having touched it.

The symptoms of poisoning, as stated above, are irritation and redness, followed by "water blisters." There is a great temptation to scratch the inflamed areas, resulting in breaking the blisters and spreading the poison.

It is an interesting fact that cattle and other herbivorous animals can eat this plant with impunity. Dogs, however, are liable to be poisoned, especially about the mouth, through contact with the poison ivy plant.

For obvious reasons, poison ivy is not a tempting plant with which to experiment. Consequently the poisonous principle is as yet a matter of some discussion. It has been considered by different investigators to be a volatile acid, volatile alkaloid, or volatile oil that caused the disease. The volatile nature of the substance was thought to explain poisoning through merely passing near the plant. However, there is considerable evidence that the poisonous principle is in reality a non-volatile oil. Very minute quantities of this irritating oil may cause the poisoning.

Regarding the length of time it takes for the disease to appear after contact with the plant, it has been found that it may vary from eighteen hours to nine days. Thus it may readily be understood that one may have been in a position to touch a plant, and after a week, when the poisoning finally results, have forgotten the occasion. This may explain many of the cases where poisoning

is alleged to have resulted from being only in the vicinity of the plant. But it may also be possible that hairs or pollen grains blown from the plant to susceptible individuals may cause poisoning—truly without any recognizable contact with it.

The most important question is, of course, what should be done to prevent or cure the disease? Answers to this are many in number. Alcohol, solution of permanganate of potassium, saleratus or sodium bicarbonate, alkaline solutions, strong soaps, etc., are found recommended as remedial agents. The justification for the use of alcohol is that it dissolves the oil. There is a great danger in using alcohol, however, namely, that it may, unless large quantities are used to completely wash the poison off, even spread the poison and cause greater penetration!

Alkalies and saleratus are efficacious because they cause a saponification of this poisonous oil, thus rendering it harmless.

Strong soap (yellow laundry soap is best because it contains more free alkali) has been tried and found effective. This is easily obtained, easily carried, and serves a double purpose; i. e., through its deturgent action effects the removal of poisonous particles, and through its alkalinity causes saponification of the poison.

It should be emphasized that after any trip where there is any possibility of poison ivy having been encountered, a thorough wash with strong soap should be resorted to.

If poisoning has occurred, careful washing with strong soap frequently, followed by a drying talcum powder, taking care that the blisters, in breaking, do not spread the poison, should result in no serious results being felt from the disease. If poisoning is severe, a doctor should of course be consulted.

Poison ivy should be exterminated wherever it is known to exist. But much less of the distress due to poisoning would result if people were acquainted with the plant, and kept on the lookout to avoid it; if preventive measures were employed to preclude poisoning (especially soap and water and a scrubbing brush); and if care and intelligence were employed when a local poisoning was found to have occurred.

G. R. BISBY.

NOTICES

The Garden is open free to the public daily, from 8 a. m. until dark; on Sundays and holidays at 10 a. m. The Laboratory Building, containing the library, herbarium, and offices, is open daily, from 9 a. m. until 5 p. m. The Conservatories are open April 1-October 1, 10 a. m.-4:30 p. m.; October 1-April 1, 10 a. m.-4 p. m.

The Brooklyn Botanic Garden is entirely dependent upon private means for the acquisition of plants. It is also the practice of the Garden to purchase all books for the library, herbarium specimens, lantern slides, and other illustrative material with private funds; the expense of printing and distributing these LEAFLETS, and a portion of the annual maintenance of the Garden is, in like manner, dependent upon membership dues and private contributions.

The Director of the Garden will be glad to furnish, on request, full information as to the conditions and privileges of membership.

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A docent will meet parties by appointment and conduct them through the Garden. This service is free to members of the Botanic Garden and to teachers with classes; to others there is a nominal charge of 25 cents an hour for parties of less than three, and 10 cents a person per hour for parties of three or more.

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Telephone: 6173 Prospect.

Mail address: Brooklyn Botanic Garden, Brooklyn, N. Y.

THE UREDINALES FOUND UPON THE ONAGRACEAE

G. R. BISBY

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The members of the family Onagraceae, while of cosmopolitan distribution, are particularly American. Western North America is especially rich in species belonging to this family. Similarly, while a few rusts upon members of the Onagraceae are scattered over many parts of the world, the majority of them are known only from America. The Sydows, in the three published volumes of their Monograph of the Uredinales, list 27 species of rusts upon the Onagraceae. Of these, 15 species are given as existing only in North America, 3 species only in South America, and 2 species both in America and in other countries. Of the species for which the Americas are not included as localities, 3 have been found to be present. Thus, of the 27 species listed by the Sydows, 23 occur in the Western Hemisphere, and 21 of these have been found in North America. In addition to the species published in the Sydows' monograph, there are *Aecidium Anograe* and *Puccinia Fuchsiae*, both known only from North America. *Puccinia Veratri*, a widely distributed species, has rather recently been found to have its aecial stage upon certain of the Onagraceae; the telial stage only is listed in Sydow, and not included above. *Puccinia Nesaeae* (Ger.) Ell. & Ev., listed in Sydow as occurring upon *Nesaea*, is misplaced, the host in reality being *Ludwigia*, a genus of the Onagraceae.

The family Onagraceae has proved perplexing to the phanerogamic taxonomists; a glance at the lack of uniformity in ideas of nomenclature and arrangement of species as represented in various floras attests to the uncertainty of specific characters in this group of plants. These very uncertainties and variabilities have given this family important consideration from an evolutionary standpoint. An extensive literature has grown around the genus *Oenothera* alone.

So, too, the rusts occurring upon these hosts have been found to be variable, uncertain, and confusing. Arthur¹ has dealt with similar conditions in the case of the rose rusts, in which the variability of the host appears to be reflected in a similar degree by the variation in the rust. In his discussion of this condition Arthur states (p. 28) that "each species of *Phragmidium* has attained a degree of orthogenetic development and a diversity of characters corresponding to the hosts on which it occurs, always, however, with a certain lag due to the inhibiting nature of parasitism." It would seem that parallel conditions as regards variability, both with the hosts and their rusts, obtain in both the Rosaceae and Onagraceae.

Considerable work has been done upon the rusts of the Onagraceae; the results, however, are rather scattered and somewhat conflicting, and the species described have seemed often to be of doubtful validity. The Sydows, as previously suggested, have done much toward systematizing the knowledge of these rusts; Holway has published valuable descriptions and notes on the species of *Puccinia* occurring upon this group. Descriptions of some of these rusts have already appeared in the North American Flora. Many other writers have added their ideas; yet it was apparent that further work upon a considerable number of collections of some of these species of rust should result in an attainment of greater order. The facilities of the Arthur herbarium have afforded to the writer an unequalled opportunity to study a large number of collections; preparation of manuscript upon the rusts for the North American Flora rendered it imperative that additional critical studies be made of Onagraceous rusts.

The ideas regarding relationship, correlation, and classification, advocated in this paper, should be considered but the elaboration of the opinions held by Dr. J. C. Arthur, and by the workers in his laboratory. It has been possible to bring together the data presented, through the courtesy of Dr. Arthur in placing the facilities of the laboratory at the writer's disposal. Furthermore, thanks are due to Messrs. F. D. Kern, C. R. Orton, C. A. Ludwig, and especially to Prof. H. S. Jackson, for much assistance.

The term "correlation," as used in this paper and by other writers from this laboratory, is intended to express an idea of relationship of rusts based on similarities of morphological characters. This simi-

¹ Arthur, J. C., North American Rose Rusts. *Torrey* 9: 21-28. 1909.

larity may be expressed in different ways. One of the earliest noted resemblances between species was that between certain *Uromyces* and *Puccinia* forms with the same life cycle, the only difference being in the possession, by the one species, of one-celled teliospores, by the other of two-celled teliospores. Fries² noted the fact that such an analogy sometimes existed. Orton³ has reviewed the literature pertaining to this type of correlation, and shown some specific instances. This kind of correlation is shown in the Onagraceae rusts by the resemblance of *Uromyces plumbarius* to *Puccinia Epilobii-tetragoni*.

A second type of correlation is that illustrated by a similarity in the characters of a short-cycled species and a long-cycled heteroeccious species bearing aecia upon the telial host of the short-cycled rust. Dietel,⁴ and about the same time, Fischer,⁵ pointed out this type of resemblance. Travelbee,⁶ from this laboratory, has briefly summarized the literature regarding this type of correlation, and listed some proven examples. This indicated relation has been successfully used to predict alternate hosts: indeed, in the Onagraceae rusts, through the similarity of the telial stage of *Puccinia Epilobii* to that of *Puccinia Veratri*, the alternate host of the latter was forecasted, as is noted later in this article.

A third type of correlation is that between two species of rust, with life cycles of different lengths, occurring upon the same or similar hosts. Fischer⁷ has indicated such a relation between two species of rust upon *Epilobium*; other possibilities are suggested in this paper.

It is obvious that a similarity of morphological characters does not of necessity reflect a phylogenetic relationship. Certainly, however, when such similarities are found between rusts upon related hosts, it is a noteworthy suggestion of a definite relationship between the rusts, and it seems to the writer that relationships may be inferred in certain cases even when there is some slight variation between the parallel characters of two such species of rust.

Races are designated in this paper as occurring within the long-

² Fries, E. M., *Summ. Veg. Scand.* 1: 514. 1846.

³ Orton, C. R., *Correlation between certain species of Puccinia and Uromyces.* *Mycol.* 4: 194-204. 1912.

⁴ Dietel, P., *Uredinales*, in Engler and Prantl, *Pflanzenfam.* 1¹⁺⁺: 69. 1897.

⁵ Fischer, Ed., *Beitr. Krypt. Schweiz* 1¹: 109. 1898.

⁶ Travelbee, H. C., *Correlation of certain long-cycled and short-cycled rusts.* *Proc. Ind. Acad. Sci.* 1914: 231-234. 1915.

⁷ Fischer, Ed., *Beitr. Krypt. Schweiz* 2²: 154-155. 1904.

cycled autoecious species discussed. The idea embodied is somewhat different from that of physiological or biological races. The latter designation of races is used, in the Uredinales, in cases where cultures have shown that there are certain restrictions upon the transference of a rust from host to host. The idea made use of here is that of morphological races—races separated upon the same ideas of differentiation upon which species are ordinarily based, but the differences being not of sufficient value nor constancy to make possible a separation into species. In the absence of cultural data, these races are suggested for convenience. The idea is somewhat that of varieties under a species. The word variety is not used, however, as that would result in a cumbersome, and perhaps inaccurate, nomenclature; a tentative division into morphological races seems to afford an opportunity to systematize the arrangement of specimens representing rather variable species.

A perfectly consistent treatment of the evening primrose rusts, embracing all the species, is now impossible. This study is therefore made primarily in an attempt to draw attention to some of the questions demanding answer, and in the hope that collections, cultures, and studies may eventually be made to clarify and arrange our knowledge of this interesting group of rusts.

The main points brought out in this paper are: the grouping together of the long-cycled autoecious forms of *Puccinia* upon the Onagraceae into one species, and the considerations involved; some notes upon the heteroecious forms which include the Onagraceae in their life cycle; some correlations indicated between different species and races; keys to aid in the diagnosis of the various rusts in question. Several incidental points are discussed. Species not known in North America are dealt with only briefly. Descriptions of several of the species under discussion are not added here, since that would appear to be an unnecessary duplication. References to descriptions easily available are given in such cases.

The keys herewith presented offer difficulties at some points, due partly, as pointed out above, to the fact that correlated species possess spore-forms morphologically indistinguishable. The different considerations, however, usually can be utilized to place a specimen. The abbreviations N.A. (North America), S.A. (South America), Eur. (Europe), etc., and the symbols O (pycnia), I (aecia), II (uredinia), and III (telia), used in places, are for brevity.

KEY, BASED UPON LIFE HISTORY

Pycnia and aecia only occurring upon Onagraceae.

Aecia diffused.

Puccinia Veratri.

Aecia in groups.

Aeciospore wall thick, 2-3 μ .

Aecidium Anograe.

Aeciospore wall thin, 1 μ .

Spores larger, 14-21 μ long.

Puccinia Peckii.

Spores smaller, 13-15 μ long (Eur.)

Aecidium Circaeae.

Pycnia, aecia, and telia occurring upon Onagraceae.

Teliospores up to 60 μ in length.

Puccinia Jussiaeae

(*Puccinia Ludwigiae*).

Puccinia Epilobii-Fleischeri.

Teliospores up to 45 μ in length (Eur.)

Pycnia, aecia, uredinia, and telia occurring upon Onagraceae.

Teliospores one-celled.

Uromyces plumbarius.

Teliospores two-celled.

Puccinia Epilobii-tetragoni.

Characters of the latter (S. A.)

Puccinia luxurians.

Life-history uncertain; possibly same as *P.*

Epilobii-tetragoni (Afr.)

Puccinia Krookii.

Uredinia and telia only occurring upon Onagraceae.

Telia within or below epidermis.

Pucciniastrum pustulatum.

Characters similar to the latter (Eur.).

Pucciniastrum Circaeae.

Pycnia (when formed) and telia occurring upon Onagraceae.

Teliospore apex scarcely thickened, 1.5-4 μ .

*Puccinia sphaeroidea?**

Teliospore wall smooth, 3 μ thick.

Teliospore wall verrucose, 1.5-2 μ thick.

Puccinia scandica.

Teliospores smaller, 13-18 by 27-37 μ .

Teliospores larger, 17-25 by 30-44 μ .

Puccinia Epilobii.

Teliospore apex considerably thickened, 5-12 μ .

Teliospores somewhat smaller, up to 40 μ .

Puccinia Circaeae.

Teliospores medium, up to 50 μ .

Puccinia Fuchsiae.

Teliospores somewhat larger, up to 60 μ .

Puccinia gigantea.

Uredinia only known upon Onagraceae (S. A.).

Uredo oenothericola.

KEY, BASED UPON SPORE FORMS INDEPENDENTLY

Aecia in groups, *i. e.*, infection local.

Aeciospore wall thick, 2-3 μ .

Aecidium Anograe.

Aeciospore wall thin, 1 μ .

Aecia small, 0.2-0.3 mm. across.

Aeciospores 15-21 μ long.

Puccinia Jussiaeae

(*Puccinia Ludwigiae*).

Aeciospores 13-15 μ long.

Aecidium Circaeae.

Aecia larger, 0.3-0.6 mm. across.

Puccinia Peckii.

* Doubtfully upon Onagraceae.

Aecia diffused, *i. e.*, infection general.

Morphological characters similar; correlated species; aeciospores usually only to 20-21 μ in length.

Similar to above, except aeciospores often up to 23-24 μ .

Uredinia without peridium; urediniospore-wall colored.

Uredinia often gregarious on spots.

Uredinia scattered; spots none; correlated.

Uredinia with peridium; urediniospore-wall colorless.

Characters similar.

Telia within or below epidermis.

Characters similar.

Telia erumpent.

Teliospores one-celled.

Teliospores two-celled.

Teliospore apex considerably thickened, 4-12 μ .

Telia scattered, not upon spots.

Characters similar; correlated.

Characters apparently those of *Puccinia Epilobii-tetragoni*.

Telia gregarious, upon spots.

Teliospores smaller, to 40 μ long.

Teliospores to 50 μ long.

Teliospores larger, to 60 μ long.

Wall cinnamon-brown.

Wall paler, especially below.

Teliospore apex little thickened, 1.5-4 μ .

Teliospore wall smooth, 3 μ thick.

Teliospore wall verrucose, 1.5-2 μ thick.

Teliospores comparatively smaller, 13-18 by 27-37 μ .

Teliospores comparatively larger, 17-25 by 30-44 μ .

Uromyces plumbarius,
Puccinia Epilobii-tetragoni,
Puccinia Epilobii-Fleischeri

Puccinia Veratri.

Uredo oenothericola.

Uromyces plumbarius,
Puccinia Epilobii-tetragoni,
(*Puccinia luxurians*,
P. Krookii).

Pucciniastrum pustulatum,
Pucciniastrum Circaeae.

Pucciniastrum pustulatum,
Pucciniastrum Circaeae.

Uromyces plumbarius.

Puccinia Epilobii-tetragoni,
Puccinia Epilobii-Fleischeri.

(*Puccinia luxurians*
Puccinia Krookii).

Puccinia Circaeae.

Puccinia Fuchsiae.

Puccinia Jussiaeae
(*Puccinia Ludwigiae*).
Puccinia gigantea.

? *Puccinia sphaeroidea*.

Puccinia scandica.

Puccinia Epilobii.

KEY TO SPECIES AND RACES, BASED UPON HOST AND INCLUDING GEOGRAPHIC DISTRIBUTION

Gayophytum; N. A., S. A.; O, I, II, III, *Puccinia*

Gayophyti race of *Puccinia Epilobii-tetragoni*.

Chamaenerion

Western N. A.; Eur.; O, I, II, III;

III spores to 40 μ , I spores usually to 20 μ .*Puccinia Gayophyti* race of *Puccinia Epilobii-tetragoni*.

N. A.; Eur.; O & I

I often to 24 μ .*Puccinia Veratri*.

N. A.; Eur.; II & III only;

III spores often within epidermis.

Pucciniastrum pustulatum.

Western N. A.; Eur.; III only;

III spores to 60 μ .*Puccinia gigantea*.*Epilobium*

Teliospore apex thickened.

As first three under *Chamaenerion*. { *Puccinia Gayophyti* race of *Puccinia Epilobii-tetragoni*,
Puccinia Veratri,
Pucciniastrum pustulatum.

Eur.; O, I, III.

Puccinia Epilobii-Fleischeri.

Afr.; uncertain.

Puccinia Krookii.

Teliospore apex little thickened

N. A.; Eur.; III only,

III spores 13-18 by 27-37 μ .*Puccinia scandica*.III spores 17-25 by 30-44 μ .*Puccinia Epilobii*.*Boisduvalia glabella* only; Western N. A.; (O, I), II,III.....*Puccinia glabella* race of *Puccinia Epilobii-tetragoni*.*Taraxia*; Western N. A.; O, I, II, III*Puccinia heterantha* race of *Puccinia Epilobii-tetragoni*.*Boisduvalia* (*P. Boisduvaliae*)*Chylisma* (*P. Oenotherae*)*Eulobus* (*P. Eulobi*)*Clarkia**Godetia* } (*P. Clarkiae*)*Phaeostoma**Sphaerostigma* (*P. Sphaerostigmatis*)*Zauchneria* (*P. Zauchneriae*)*Gaura*{ O, I, II, III; *Puccinia Oenotherae* race of
Western N. A.; *Puccinia Epilobii-tetragoni*.N. A.; O, I, II, III; aecia diffused *Uromyces gauri-**nus* race of *Uromyces plumbarius*.

N. A.; O, I; aecia grouped.

Puccinia Peckii.*Kneiffia*; N. A., O, I, II, III.*Uromyces Oenotherae* race of *Uromyces plumbarius*.*Oenothera*

N. A.; O, I, grouped.

Puccinia Peckii.

N. A.; O, I, II, III; aecia diffused.

III spores one-celled.

Uromyces Oenotherae race of *Uromyces plumbarius*.

III spores two-celled.

? *Puccinia Oenotherae* race of *Puccinia Epilobii-tetragoni*.

- S. A.; O, I, II, III (?).
 S. A.; II only known.
Luxaria; N. A.; O, I, II, III.
Uromyces plumbarius race of *Uromyces plumbarius*.
- Pachylopus*
 N. A.; O, I, II, III; aecia diffused
Uromyces plumbarius race of *Uromyces plumbarius*.
 N. A.; O, I; aecia grouped. *Puccinia Peckii*.
- Onagra*
 N. A.; O, I, II, III; aecia diffused
Uromyces plumbarius race of *Uromyces plumbarius*.
 N. A.; O, I; aecia grouped. *Puccinia Peckii*.
- Megapterum*, N. A.; O, I, II, III
Uromyces Fremontii race of *Uromyces plumbarius*.
Meriolix, N. A.; O, I. *Puccinia Peckii*.
- Circaea*
 N. A.; Eur.; III; III erumpent *Puccinia Circaeae*.
 Eur.; II, III; III not erumpent. *Pucciniastrum Circaeae*.
 Eur.; O, I. *Aecidium Circaeae*.
Anogra, central U. S.; O, I. *Aecidium Anograe*.
- Jussiaea*
 N. A.; S. A.; I, III; spores up to $54\ \mu$ long. *Puccinia Jussiaeae* (*Puccinia Ludwigiae*).
 Western N. A.; III only; spores up to $32\ \mu$ long. . . . ? *Puccinia sphaeroidea*.
Ludwigia, N. A.; O, I, III. *Puccinia Jussiaeae* (*Puccinia Ludwigiae*).
Fuchsia, Mexico; III only. *Puccinia Fuchsiae*.

I. AECIDIUM ANOGRAE Arthur, Bull. Torrey Club 28: 664. 1901.

O. Pycnia amphigenous, grouped on the spots with the aecia, inconspicuous, subepidermal, honey-yellow becoming brownish, globose, $100\text{--}120\ \mu$ in diameter by $80\text{--}100\ \mu$ in height; ostiolar filaments $30\text{--}80\ \mu$ long.

I. Aecia amphigenous, chiefly hypophyllous, gregarious on roundish or irregular reddened spots, cylindrical, $0.2\text{--}0.3\ \text{mm.}$ in diameter by $0.5\text{--}0.6\ \text{mm.}$ in height; peridium white, margin erect, toothed; peridial cells rectangular, $18\text{--}24\ \mu$ by $22\text{--}35\ \mu$, slightly overlapping, the outer wall $6\text{--}10\ \mu$, striate, the inner wall $3\text{--}5\ \mu$, coarsely verrucose; aeciospores irregularly globoid or ellipsoid, $18\text{--}23\ \mu$ by $22\text{--}26\ \mu$; wall pale yellow, thick, $2\text{--}3\ \mu$, evenly verrucose.

ON ONAGRACEAE: *Anogra pallida* (Lindl.) Britt. (*Oenothera pallida* Lindl., *Anogra Vreelandii* Rydb.) Nebraska.

TYPE LOCALITY: Long Pine, Nebraska, on *Anogra pallida*.

DISTRIBUTION: Known only from the dry northwestern part of Nebraska.

EXSICCATI: Barth., Fungi Columb. 2601.

Additional collections and data allow the above expansion of the original description. This *Aecidium*, at present known only from the

Niobrara river valley in Nebraska, is distinctive, possessing cylindrical aecia and large, thick walled aeciospores. The telial stage perhaps occurs upon some Monocotyledonous host; quite possibly upon a sedge or a grass. One possibility, judging by the codistribution of host and rust, appeared to be *Puccinia eminens* Kern on *Carex Backii* Boot. An unreported culture in this laboratory, was, however, unsuccessful, and no definite morphological characters of the two species serve to indicate a relation.

2. *AECIDIUM CIRCAEAE* Cesati & Mont., in Montague, Syll. Gen. Spec. Crypt.: 312. 1856.

SYNONYMY: *Caeoma epilobiatum* Link, in Willd., Sp. Pl. 6²: 59. 1825. (In part) *Aecidium Circaeae* Cesati in Rabenh. Herb. Mycol. No. 372. 1861.

LITERATURE: Winter, in Rabenh. Krypt. Fl. 1: 266. 1881. Saccardo, Syll. Fung. 7: 791. 1888. Schroeter, Pilze Schles. 1: 379. 1889. Klebahn, Krypt. Mark Brand 5^a: 870. 1914.

This form, known only from Europe, on *Circaea*, has not yet been connected with a telial stage. Klebahn points to the fact that *Brachypodium silvaticum* Roem. & Schult. often grows in association, but he was unable to prove a connection with the rust *Puccinia Baryi* (Berk. & Br.) Winter. A comparison of these two forms fails to give a clue to a relationship between them.

The name *Caeoma epilobiatum* Link is used by Saccardo and by Klebahn as in part a synonym. This name is discussed further in this paper under *Puccinia Epilobii-tetragoni*.

3. *PUCCINIASTRUM PUSTULATUM* (Pers.) Dietel, in Engler & Prantl, Pflanzenfam. 1¹⁺⁺: 47. 1897.

DESCRIPTION: N. Amer. Fl. 7: 107. 1907.

LITERATURE: Saccardo, Syll. Fung. 7: 762. 1888. Schroeter, Pilze Schles. 1: 364. 1889. Klebahn, Krypt. Mark Brand. 5^a: 831. 1914. Sydow, Monogr. Ured. 3: 444. 1915.

Pucciniastrum Abieti-chamaenerii Kleb. is united, in the North American Flora, with *Pucciniastrum pustulatum*. There are but slight differences in the morphological characters of the two species. Cultures, made in America since the publication of the description in the Flora, and substantiating European cultures, have been successful, however, only with the *Pucciniastrum Abieti-chamaenerii* form. It would seem, therefore, that the two forms might well now be considered as separate races.

Some confusion has existed concerning the synonymy of this species. Further study has shown that the synonymy, as given with the description in the North American Flora, should be revised as follows: *Uredo Epilobii* DC. in Lam. & DC. Fl. Franç. 6: 73. 1815; and *Caeoma Epilobii* Link, in Willd. Sp. Pl. 6²: 29. 1825, are synonyms of *Puccinia Epilobii-tetragoni*, and are discussed in this paper under that species. In the place of *Caeoma Epilobii* in the Flora, should be listed *Caeoma Onagrarum* Link, in Willd. Sp. Pl. 6²: 29. 1825. (In part.) Following the latter name should be added *Erysibe pustulata Epilobium* Wallr., Fl. Crypt. Germ. 2: 198. 1833. *Me-lampsora Chamaenerii* Rost., Medd. Bot. For. Kjöbenhavn. 1: 77. 1884 (nomen nudum; no description) might be added to the synonymy, and also *Pucciniastrum Chamaenerii* Rostr., Plantepatol. 304. 1902.

The aecia of *Pucciniastrum pustulatum* (or, more accurately, of *Pucciniastrum Abieti-chamaenerii*) were unknown in America at the date of publication in the North American Flora. Fraser (Mycol. 4: 176-177. 1912) first cultured this rust in America. Aecia have been found upon Pinaceae in America, and are represented in the herbarium as follows: on *Abies balsamea* (L.) Mill., Nova Scotia, Fraser, 1911; Michigan, Kauffman, 1914; Vermont, Orton, 1913; Wisconsin, Cheney, 1906; on *Abies concolor* (Gord.) Parry, Colorado, Bethel, 1903, 1909, 1913; on *Abies grandis* Lindl., Oregon, Jackson, 1915; Idaho, Weir, 1915; on *Abies lasiocarpa* (Hook.) Nutt., British Columbia, Holway, 1907; Oregon, Jackson, 1914; Colorado, Bethel, 1915.

The aecia of this species as found in America, produce spores somewhat larger than those of European collections, being 13-18 by 17-23 μ here, and but 10-14 by 13-21 μ in Europe. No other difference is noted.

The range of the uredinia and telia of this species has also been extended, the following additions having been made since the publication in 1907: to *Chamaenerion angustifolium* (L.) Scop. add New Mexico, Oregon, West Virginia; Alberta, British Columbia, Nova Scotia. To *Epilobium adenocaulon* Haussk. add Idaho, North Dakota, Oregon, South Dakota, Utah, Virginia, Washington, West Virginia, Wisconsin, Wyoming; British Columbia. Add *Epilobium affine* Bong., Alaska. To *Epilobium anagallidifolium* Lam., add Utah. Add *Epilobium novomexicanum* Hausskn., New Mexico; *Epilobium californicum* Hausskn., California; and *Epilobium brevistylum* Barbey, Oregon.

4. PUCCINIASTRUM CIRCAEAE (Thüm.) Speg., Dec. Mycol. Ital. No. 65. 1879.

LITERATURE: Saccardo, Syll. Fung. 7: 763. 1888. Schroeter, Pilze Schles. 1: 364. 1889. Klebahn, Krypt. Mark Brand. 5^a: 833. 1914. Sydow, Monogr. Ured. 3: 445. 1915.

This European species upon *Circaea* presents no very tangible morphological differences from *Pucciniastrum pustulatum*. The hosts are different. Cultures, moreover, have so far failed to produce infection upon or from *Abies*, so that this species may well be considered to be distinct.

Klebahn (*l. c.*) gives some evidence for his suggestion that perhaps an overwintering of the rust occurs in the rhizomes of the host.

The synonym *Erysibe pustulata Circaeae* Wallr., Fl. Crypt. Germ. 2: 198. 1833, does not seem to appear in recent literature.

5. UROMYCES PLUMBARIUS Peck, Bot. Gaz. 4: 127. 1879.

DESCRIPTIONS: N. Amer. Fl. 7: 262. 1912. Sydow, Monogr. Ured. 1: 54-56. 1909.

This American species, treated here as in the North American Flora, represents a combination of four species described by different authors upon different species of host. This somewhat variable species falls into morphological races, corresponding in a general way with previously described species, as follows: (1) on *Gaura* (*Uromyces Gaurinus*). This race possesses teliospores of moderate size (16-23 by 24-33 μ), with the apex thickened the least of those of any of the races, 4-7 μ . A suggestion of verrucose markings can sometimes be seen upon the teliospores of this race. (2) On *Kneiffia* and *Oenothera* (*Uromyces Oenotherae*). This race is distinguished by dark-colored teliospores, with the apex the thickest of those of any of the races, 7-14 μ . The apex is often pointed, and the pedicel length the greatest in this species. (3) On *Luxauwia*, *Pachylophus*, and *Onagra* (*Uromyces plumbarius*). This race has the smallest teliospores (14-20 by 21-28 μ), with the apex but moderately thickened. The teliospores have been found to be very finely and inconspicuously verrucose, hardly noticeable unless the spores are viewed with the oil immersion. (4) On *Megapterium Fremontii* (*Uromyces Fremontii*). This race possesses teliospores with the thickest walls, sometimes to 3 μ . The teliospores are comparatively narrow and long.

The correlation of this species and these races with the corre-

sponding autoecious long-cycled *Puccinia* is noted under *Puccinia Epilobii-tetragoni*.

The following additions may now be made to the range and hosts listed under the description in the Flora: add *Gaura induta* Woot. & Standley, New Mexico; add *Oenothera runcinata* (Engelm.) Small, New Jersey; to *Onagra biennis* add Delaware and Missouri; to *Pachylophus macroglottis* add Colorado; to *Pachylophus montanus* add Montana and Utah. To the exsiccati the following additions have appeared: Barth. Fungi Columb. 3893 and Barth. N. Am. Ured. 493, 596, 1396 and 1495.

6. PUCCINIA EPILOBII-TETRAGONI (DC.) Winter, in Rabenh. Krypt. Fl. 1: 214. 1881.

LITERATURE: Plowright, Monogr. Brit. Ured. 152-153. 1889. Sydow, Monogr. Ured. 1: 423-435. 1903. Fischer, Beitr. Krypt. Schweiz 2²: 152-153. 1904. McAlpine, Rusts Austral. 170. 1906. Holway, N. Amer. Ured. 1: 74-79. 1907. Bubak, Pilze Boehmens 1: 67. 1908. Grove, Brit. Rust Fungi 198-200. 1913. Lind, Danish Fungi 319. 1913. Klebahn, Krypt. Mark Brand. 5^a: 335-337. 1914. Saccardo, Syll. Fung., various volumes and pages, under the different names.

SYNONYMY:

- Uredo vagans* α *Epilobii-tetragoni* DC. Fl. Franç., 2: 228. 1805.
- Aecidium Epilobii* DC. Fl. Franç., 2: 238. 1805.
- Uredo Epilobii* DC. Fl. Franç., 6: 73. 1815.
- Puccinia pulverulenta* Grev. Fl. Edinb. 432. 1824.
- Caeoma Epilobii* Link, in Willd. Sp. Pl. 6²: 29. 1825.
- Caeoma Epilobiatum* Link, in Willd. Sp. Pl. 6²: 59. 1825. p.p.
- Puccinia tenuistipes* Opiz, Seznam Rost. Kvét. Césté. 139. 1852.
- Trichobasis Epilobii* Berk. Outl. 333. 1860.
- Puccinia Gayophyti* Billings, in King Geol. Expl. 40th Par. 5: 414. 1871.
- Aecidium pallidum* Schneid. Jahresb. Schles. Ges. 71. 1872.
- Puccinia Oenotherae* Vize, Grev. 5: 109. 1877.
- Aecidium Gayophyti* Vize, Grev. 7: 12. 1878.
- Puccinia Boisduvaliae* Peck, Bot. Gaz. 7: 45. 1882.
- Puccinia Gayophyti* Peck, Bot. Gaz. 7: 56. 1882.
- Puccinia Clarkiae* Peck, Bull. Torrey Club 11: 49. 1884.
- Puccinia Epilobii* Schroet. Pilz. Schles. 1: 319. 1889.
- Puccinia intermedia* Diet. & Holw. Bot. Gaz. 18: 254. 1893.
- Puccinia heterantha* Ell. & Ev. Erythea 1: 204. 1893.
- Puccinia Eulobi* Diet. & Holw. Erythea 1: 249. 1893.
- Aecidium Clarkiae* Diet. & Holw. Erythea 2: 129. 1894.
- Puccinia Sphaerostigmatis* Diet. & Neg. Bot. Jahrb. Engler 22: 353. 1896.
- Dicaeoma Boisduvaliae* Kuntze, Rev. Gen. Pl. 3²: 468. 1898.
- Dicaeoma Clarkiae* Kuntze, Rev. Gen. Pl. 3²: 468. 1898.

- Dicaeoma Gayophyti* Kuntze, Rev. Gen. Pl. 3³: 468. 1898.
Dicaeoma heteranthum Kuntze, Rev. Gen. Pl. 3³: 469. 1898.
Dicaeoma intermedium Kuntze, Rev. Gen. Pl. 3³: 469. 1898.
Dicaeoma Oenotherae Kuntze, Rev. Gen. Pl. 3³: 469. 1898.
Puccinia Gayophyti Speg. Anal. Mus. Nac. B. Ayres III. 1: 63. 1902.
Puccinia Zauchneriae Sydow, Monogr. Ured. 1: 435. 1903.
Puccinia glabella Holway, N. Amer. Ured. 1: 76. 1907.

O. Pycnia amphigenous, among or opposite the aecia, scattered, inconspicuous, subepidermal, honey-yellow becoming brown, globose, 85-150 μ in diameter by 110-170 μ in height; ostiolar filaments 30-65 μ long.

I. Aecia amphigenous, chiefly hypophyllous, scattered, from a diffused mycelium, numerous, often covering the entire leaf surface, cupulate or sometimes short-cylindrical, 0.2-0.5 mm. across; peridium white, margin recurved, lacerate; peridial cells rhomboidal, 13-22 by 22-36 μ , overlapping, the outer wall 5-10 μ thick, striate, the inner wall thinner, 3-6 μ , moderately verrucose; aeciospores irregularly globoid, angular, or ellipsoid, 13-20 by 13-23 μ (usually only to 20 μ in length); wall colorless, thin, 1 μ , minutely verrucose.

II. Uredinia amphigenous, often only hypophyllous, numerous, scattered, occasionally confluent, roundish, small, 0.1-0.8 mm. across, rather early naked, pulverulent, cinnamon-brown, ruptured epidermis noticeable; urediniospores ellipsoid. obovoid, or globoid, flattened slightly on two opposite sides, 15-26 by 19-31 μ ; wall cinnamon-brown, thickness somewhat variable, 1.5-3 μ , moderately or sometimes closely echinulate, the pores 2, equatorial, rarely slightly superequatorial, in lighter colored areas in the flattened sides.

III. Telia amphigenous, sometimes caulicolous, numerous, scattered or sometimes confluent, roundish, rather small, 0.2-1 mm. across, early naked, pulverulent or sometimes compact, dark chestnut-brown, ruptured epidermis inconspicuous; teliospores ellipsoid or obovoid, rounded or somewhat narrowed at one or both ends, somewhat variable upon different hosts, 14-27 by 23-50 μ , usually somewhat constricted at the septum; wall cinnamon- or chestnut-brown, 1.5-3 μ thick, occasionally up to 4 μ thick, apex thicker, 4-12 μ , sometimes finely and inconspicuously verrucose; pedicel pale, rather fragile, usually broken away, but sometimes twice the length of the spore.

ON ONAGRACEAE:

- Boisduvalia densiflora* (Lindl.) Wats., California, Idaho, Oregon, Washington.
Boisduvalia densiflora imbricata Greene, California.
Boisduvalia glabella (Nutt.) Walp., Idaho, Nevada, Oregon.
Boisduvalia sparsiflora Heller, California.
Boisduvalia stricta (A. Gray) Greene (*B. Torreyi* Wats.), Oregon.
Chamaenerion latifolium (L.) Sweet (*Epilobium latifolium* L.), Alaska.
Chylisma cardiophylla (Torr.) Small (*Oenothera cardiophylla* Torr.), California.
Chylisma hirta A. Nels., Nevada.
Chylisma scapoidea scorsa A. Nels., Idaho.
Clarkia pulchella Pursh, Idaho, Oregon, Washington.
Epilobium adenocaulon Hausskn., Montana, New Mexico, Washington; Alaska.
Epilobium affine Bong., Alaska.

- Epilobium clavatum* Trel. Montana.
Epilobium minutum Lindl., Oregon.
Epilobium paniculatum Nutt., California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming.
Epilobium perplexans Trel., Idaho.
Eulachis californicus Nutt., California.
Gayophytum caesium Torr. & Gray, Idaho, Nevada, Utah, Wyoming.
Gayophytum diffusum Torr. & Gray, California, Idaho, Utah.
Gayophytum lasiospermum Greene, Utah.
Gayophytum Nuttallii Torr. & Gray, Idaho.
Gayophytum racemosum Torr. & Gray, Colorado, Idaho.
Gayophytum ramosissimum Torr. & Gray (*G. intermedium* Rydb.), Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Wyoming.
Gayophytum sp., Arizona, Washington.
Godetia amoena (Lehm.) Lilja, California.
Godetia epilobioides (Nutt.) Wats., Nevada, Washington.
Godetia grandiflora Lindl., California.
Phacostema elegans (Dougl.) A. Nels. (*Clarkia elegans* Dougl.), California.
Phacostema rhomboidea (Dougl.) A. Nels. (*Clarkia rhomboidea* Dougl.), California, Washington.
Sphaerostigma andinum (Nutt.) Walp. (*Oenothera andina* Nutt.), Idaho, Washington.
Sphaerostigma bistorta (Nutt.) Walp. (*Oenothera bistorta* Nutt.), California.
Sphaerostigma Boothii (Dougl.) Walp. (*Oenothera Boothii* Dougl.), Oregon, Washington.
Sphaerostigma contortum (Dougl.) Walp. (*Oenothera contorta* Dougl.), California, Washington.
Sphaerostigma coccineum (H. & A.) Small (*Oenothera gauraefolia* Torr. & Gray), California.
Sphaerostigma dentatum (Cav.) Walp. (*Oenothera dentata* Cav.), Oregon.
Sphaerostigma hirtellum (Greene) Small (*Oenothera hirtella* Greene), California.
Sphaerostigma implexa A. Nels., Idaho.
Sphaerostigma micranthum (Hornem.) Walp. (*Oenothera micrantha* Hornem.), California.
Sphaerostigma pubens (S. Wats.) Rydb. (*Oenothera strigulosa pubens* S. Wats.), California.
Sphaerostigma spirale (Lehm.) Walp. (*Oenothera spiralis* Hook.). California.
Sphaerostigma utahense Small, Utah.
Sphaerostigma Veitchianum (Hook.) Small (*Oenothera bistorta Veitchiana* Hook.), California.
Sphaerostigma viridescens (Lehm.) Walp. (*Oenothera viridescens* Lehm.), California.
Taraxia brevifolia Nutt., Montana.
Taraxia graciliflora (H. & A.) Raim. (*Oenothera graciliflora* H. & A.), California.
Taraxia heterantha (Nutt.) Small, Wyoming.
Taraxia longiflora Nutt. (*Oenothera Nuttallii* Torr. & Gray), Nevada.

Taraxia ovata (Nutt.) Small (*Oenothera ovata* Nutt.), California.

Taraxia subacaulis (Pursh) Rydb. (*Oenothera heterantha* Nutt.), Colorado, Idaho, Montana, Nevada, Utah, Wyoming.

Zauchneria californica Presl., California.

Zauchneria Garrettii A. Nels., Utah.

TYPE LOCALITY: France, on *Epilobium tetragonum*.

DISTRIBUTION: From the western part of the Dakotas westward to the coast, and from Alaska to New Mexico and California; also (in part) in Europe, Asia, Australia, and South America.

ILLUSTRATIONS: Holway, N. Amer. Ured. 1: pl. 33, f. 113a & b; pl. 34, f. 113c to e, 114, 115a & b; pl. 35, f. 115 c to h; pl. 36, f. 116 and 117. Beitr. Krypt. Schweiz 2²: f. 118.

EXSICCATI: Barth. Fungi Columb. 2469, 2558, 2771, 3750, 3752, 4767; Barth. N. Amer. Ured. 159, 295, 341, 356, 438, 439, 856, 953, 1148, 1252, 1262, 1350, 1359, 1440, 1579; Clements, Crypt. Form. Colo. 561; Ell. & Ev. Fungi Columb. 1851; Ell. & Ev. N. Amer. Fungi 1846, 2986, 2995, 3139, 3140, 3477, Garrett, Fungi Utah. 49, 50, 86, 92, 110, 145, 162, 173; Sydow, Ured. 864, 865, 866, 874, 875, 881, 1063, 1064, 1768, 1918, 1919.

As the synonymy indicates, some fifteen separately described and named long-cycled autoecious species of *Puccinia* upon the Onagraceae have been here combined as one species. Several of these names have been considered to be synonyms by different authors. For example, Holway considers *Puccinia pulverulenta* and *Puccinia intermedia* to be synonymous with *Puccinia Epilobii-tetragoni*, and *Puccinia Boiss-duvaliae*, *Puccinia Clarkiae*, *Puccinia Eulobi* and *Puccinia Sphaerostigmatis* to be hardly distinguishable from *Puccinia Oenotherae*. *Puccinia Gayophyti* has been described three separate times by independent authors. Other earlier repetitions in description, under the same names, are not included.

It was not without some hesitation that it was decided thus to combine all these forms. In first going over a few specimens of each species, for the sake of comparison, it was obvious that considerable differences existed. Some of the specimens showed dark, chestnut-brown teliospores, others lighter, cinnamon-brown; some specimens showed teliospores with scarcely thickened apices, others, thickened to 12 or 13 μ ; some were verrucose, others smooth; the size of these spores varied considerably. It seemed that surely several species of rust existed upon these hosts, as other workers had concluded; to consider combining them appealed to the writer as an easy and therefore inexcusable dodging of the issue. It was remembered, further, that this rust upon *Epilobium* occurs over most of the world; upon most of the other hosts, only in America. However, as the study

progressed, other considerations were forced upon the attention of the writer: as already noted, one has here to deal with closely related, variable hosts, and it is perhaps not strange that one should find the rusts also to be variable, and that the related American hosts should bear related rusts. In the course of the study here, between two and three hundred specimens of these autoecious rusts in the Arthur herbarium, assigned tentatively to different specific names, were examined. With the continuation of the work, it became more and more evident that the differences separating a few collections were neither of sufficient value nor constancy, as evidenced by an examination of a large number of collections, to render possible a division of species upon a morphological basis. A few examples may aid in corroborating this view.

The host *Boisduvalia* affords the most striking evidence of the variability of the rusts upon the Onagraceae. Holway, in his work upon the North American Uredineae, very logically described as a new species, *Puccinia glabella*, the rust occurring upon *Boisduvalia glabella* (Nutt.) Walp. This description was from a specimen distributed by Griffiths, West American Fungi 385, as *Puccinia Boisduvaliae* Peck. Holway points out that this rust upon *Boisduvalia glabella* is a very different thing from the rust occurring upon other species of *Boisduvalia*: *Puccinia glabella* has small teliospores (Holway gives 15–18 by 25–32 μ), with the apex not at all or only slightly thickened; *Puccinia Boisduvaliae* possesses larger teliospores, usually much thickened at the apex. In a recent visit to the University of Wyoming, however, Dr. Arthur obtained further specimens of rusts upon Onagraceous hosts. Among these was a collection upon *Boisduvalia glabella* showing somewhat larger teliospores, with thicker apices, than was shown by other specimens in the herbarium upon this host. The measurements of the teliospores of this specimen of *Puccinia glabella* were 15–19 by 26–35 μ , the apex 4–7 μ . From the same herbarium a specimen was secured upon *Boisduvalia densiflora* (Lindl.) Wats., with spores but little larger, 16–23 by 32–39 μ , and the apex the same thickness, 4–7 μ . Another collection in the herbarium upon *Boisduvalia densiflora* shows teliospores 18–26 by 32–53 μ , with the apex 7–12 μ . That an error in identification of the host is not the explanation here, is indicated, not only by an examination of the material, and a consideration of the carefulness of the collectors, but by the fact that other specimens of *Boisduvalia* rusts

show similar variability; in fact, a gradual gradation is to be noted. Here then, the two extremes in these forms of Onagraceous rusts occur upon the same genus of host, to a great extent upon the same species, and shade by degrees the one into the other.

The genus *Chylisma* shows much variation in the rust upon different species; for example, a collection upon *Chylisma hirta* A. Nels. possesses teliospores 21–24 by 37–50 μ , the wall chestnut-brown, smooth, the apex 7–11 μ , the pedicel once or twice the length of the spore; another collection upon *Chylisma scapoidea scorsa* A. Nels. shows teliospores but 16–20 by 26–34 μ , the wall from cinnamon- to chestnut-brown, appearing almost as if verrucose, the apex but 4–7 μ thick, the pedicel short.

The evidence obtained from the large number of collections points unquestionably toward great variability in morphological characters within the forms upon these Onagraceous hosts. In a general way differences are found between the rusts upon these different hosts which ordinarily may be utilized to indicate the placing of the rust within morphological races, as is indicated later in this article; yet specific distinctions, it seems to the writer, can not be drawn. It is significant that, in the work upon the correlated long-cycled autoecious *Uromyces* forms upon the Onagraceae, of which four species had been described, it was considered desirable also to combine them, as already published in the North American Flora.

The long synonymy involves some names about which confusion exists in the literature. The name *Aecidium pulchellum* Schrad. is omitted from the synonymy, being listed by DeCandolle as a synonym of his *Aecidium Epilobii* in Fl. Fr. 2: 238. 1805. As no reference to any publication is given, it may be assumed that *Aecidium pulchellum* was a manuscript or herbarium name, never established. *Puccinia tenuistipes* Opiz is included on the authority of Sydow, who states that it occurs on *Epilobium hirtum* and is fully identical with *Puccinia Epilobii-tetragoni*. As listed by Opiz, Seznam Rost. Kvet. Ceske 139. 1852, one can hardly determine what is referred to. *Aecidium pallidum* Schneid. is also included on authority of Sydow (*l. c.*) also Schroeter (*l. c.*, p. 319), it having been found that Schneider erroneously determined his host plant, considering it to be *Lythrum Salicaria*, whereas Schroeter finds the host in reality to be *Epilobium hirsutum*.

Puccinia Epilobii DC. Fl. Fr. 6: 61. 1815, is used by Saccardo,

Syll. Fung. 7: 608. 1888, and by others, as the name for this species here considered as *Puccinia Epilobii-tetragoni*. The original *Puccinia Epilobii* of DeCandolle refers, however, to the short-cycled species still known under that name. Saccardo in Syll. Fung. 17: 245. 1905, corrects the earlier mistake. Kuntze has made the combination *Dicaeoma Epilobii* Rev. Gen. 3³: 469. 1898, which name may be considered to be a synonym of the short-cycled *Puccinia Epilobii* DC.

The names *Uredo Epilobii* DC. and *Caeoma Epilobii* Link, included in the synonymy, have been particularly confused in the literature. Both these names have been used in the North American Flora as synonyms of *Pucciniastrum pustulatum* (Pers.) Dietel, and both have been used by the Sydows (Monog. Ured.) as synonyms both of *Pucciniastrum pustulatum* and *Puccinia Epilobii-tetragoni*. *Uredo Epilobii* is described by DeCandolle to take the place of his *Uredo vagans* var. *Epilobii-tetragoni*, which latter name he includes as a synonym. DeCandolle further says in his description that this *Uredo* is often found associated with *Aecidium Epilobii*, and he contrasts *Uredo Epilobii* with *Uredo pustulata* and *Puccinia Epilobii*. It is evident that this name in question refers to *Puccinia Epilobii-tetragoni* and not to a *Pucciniastrum*. *Caeoma Epilobii* is given by Link as having for synonyms *Uredo Epilobii* DC. and *Uredo vagans Epilobii* DC. (meaning *Uredo vagans Epilobii-tetragoni*, since he gives as reference Fl. Fr. 2: 228). Link briefly describes *Caeoma Epilobii* as possessing ruptured epidermis surrounding, and as occurring upon *Epilobium tetragonum*. This name very evidently must be considered to be a synonym of *Puccinia Epilobii-tetragoni*.

Caeoma Epilobiatum is given by Link with *Aecidium Epilobii* DC. as a synonym. This *Caeoma* name has been used by the Sydows and others as a synonym of *Puccinia Epilobii-tetragoni*. It has also been used as a synonym of *Aecidium Circaeae* Cesati and Mont., as indicated previously in this paper. Link describes his species as "maculis oblitteratis," with a pseudoperidium, and orange or yellow spores, and as inhabiting leaves of *Epilobium* and *Circaea* in Europe. It would seem that, as Klebahn and others indicate, this name of Link may be used as a synonym of *Aecidium Circaeae* in part, and that it might refer also in part to *Puccinia Epilobii-tetragoni*.

The majority of the synonyms refer to descriptions made when this rust, with apparent differences, was found upon a new host, and to combinations made from these names. It is only when a large

number of collections are at hand that the value of the differences, indicated by the various descriptions, can be determined.

Some reasons for the continuation of the specific name *Epilobii-tetragoni* may not be out of place here. While used first as a varietal name, and resulting now in a long trinomial, its retention seems advisable in view of common usage and establishment by leading authorities. Furthermore, the two names following this in priority can scarcely be used, the *Puccinia* combination referring to a short-cycled form. Plowright and Grove have used the name *Puccinia pulverulenta* Grev., but this latter name is hardly in use outside of Great Britain.

Pycnia are not frequent in this species, since, as has been often pointed out, the aecial mycelium is perennial. Pycnia are found, it may be supposed, when infection with basidiospores occurs. Plowright (Monog. Ured. 152. 1889) states that in 1882 he obtained aecia from the sowing of aeciospores upon *Epilobium hirsutum*. Grove, however, doubts the validity of the result. Indeed, it is hardly to be expected that a rust should have two repeating spore stages; yet probably not beyond the bounds of possibility. Dietel (Flora 81: 401. 1895) discusses this production of secondary aecia, and states that he obtained uredinia from sowing aeciospores. The aecia vary somewhat in shape, depending upon conditions, being sometimes short cylindric, usually cupulate, sometimes oval. The aeciospores vary slightly in size. It has been found rather infrequently that the aeciospores attain a length of $23\ \mu$, ordinarily being only up to $20\ \mu$ in length. This is especially true in cases in which uredinia or telia are present with the aecia. As far as can be determined from collections and studies thus far made, no definite distinction can be found between the aecia of *Puccinia Epilobii-tetragoni* and the aecia of *Puccinia Veratri*, save that the aeciospores of collections placed with the latter are ordinarily slightly larger, being more frequently up to $23\ \mu$ in length. These points are touched upon under *Puccinia Veratri* in this article.

It is, of course, possible that mixed infections may occur upon species of *Epilobium*. The aecia of *Puccinia Veratri* and the uredinia and telia of *Puccinia Epilobii-tetragoni* might easily be found occurring upon the same plant. Field collections of such infections would ordinarily be considered as only *Puccinia Epilobii-tetragoni*.

The uredinia and urediniospores are rather constant for this

species. Such variations as occur are considered in the discussion of the races.

The telia and teliospores show the greatest variation. It has been chiefly upon teliospore characters that specific differences have been previously indicated. Some telia are pulverulent, some more compact. There is considerable variation as to size of telia. The teliospores, in some collections and upon some species of host, are somewhat verrucose; the apical thickening, the size, the pedicel length, and in a measure, the color, likewise vary. While these variations are not altogether constant, some of them can be made use of in separating races, as is indicated later.

Holway (N. Amer. Ured. 1: 76) points out that *Puccinia Epilobii-tetragoni* shows a tendency to produce only aecia and telia at higher altitudes. This is a condition that has been previously observed with rusts. (See Magnus⁸ and Fischer,⁹ and further data under *Puccinia Epilobii-Fleischeri*.)

Intermingling of the perennial mycelium producing aecia and the local mycelium producing uredinia and telia, is frequently evidenced. So too, cases are found in which local gametophytic and sporophytic mycelia are intermingled, pycnia, aecia, and uredinia or telia or both, being sometimes found close together upon the same leaf. This point affords an opportunity for further study.

South American, European, and other foreign collections of this rust, upon *Epilobium*, as represented in the Arthur herbarium, show no morphological characters different from those of North American collections.

From the data at hand, as previously indicated, it appears that *Puccinia Epilobii-tetragoni* is a very variable species; these variations can be made use of in assigning morphological races to this species. To Mr. C. A. Ludwig thanks are due for a certain amount of the preliminary work pertaining to the separation of these races. The races are, in general, as follows:

1. *Puccinia Gayophyti* race. This race occurs upon *Gayophytum* (*Puccinia Gayophyti*) and *Chamaenerion* and *Epilobium* (*P. Epilobii-tetragoni*, *P. pulverulenta*, *P. intermedia*). The hosts of this race are very similar as to vegetative characters; so too are the forms of this

⁸ Magnus, P., Bericht. Deutsch. Bot. Ges. 11: 453-464. 1893, and Hedw. Beibl. 39: 147-150. 1900.

⁹ Fischer, Ed., Verh. Schweiz Nat. Ges. Luzern 88: 47. 1906.

rust which they bear. This race is quite uniform and unvariable, and almost of world wide distribution. The apex of the teliospore is, in this race, but moderately thickened, $3-7\ \mu$, the wall cinnamon-brown, often finely verrucose. Holway separates *Puccinia Epilobii-tetragoni* upon *Epilobium* from *P. Gayophyti* chiefly by the position of the germ pores of the teliospores, which in *Puccinia Epilobii-tetragoni*, as he considered the species, he finds are one or two in the lower cell, midway between the septum and base of the spore. This distinction in general holds, but has not been found of absolute constancy. This race is rather well correlated with the *Uromyces Gaurinus* race of *Uromyces plumbarius*.

2. *Puccinia glabella* race, on *Boisduvalia glabella*. But few specimens have been collected from this host. This race possesses the the smallest teliospores, $22-39\ \mu$ in length, with the apex but slightly thickened, $2-7\ \mu$, the wall cinnamon-brown, rather paler below. The urediniospores have rather thick walls, $1.5-3\ \mu$. This seems on the whole to be a good race, although many collections of the *Puccinia Gayophyti* race show characters quite as in this race, and other *Boisduvalia* rusts sometimes approach this.

3. *Puccinia heterantha* race, on *Taraxia*. This race is distinguished by thick walled teliospores, $1.5-3\ \mu$, rather dark in color, cinnamon-to chestnut-brown, with the apex but moderately thickened, $3-7\ \mu$. Considerable evidence of correlation between the *Uromyces Fremontii* race of *Uromyces plumbarius* is shown.

4. *Puccinia Oenotherae* race. On *Boisduvalia* [excepting *Boisduvalia glabella*] (*Puccinia Boisduvaliae*), *Clarkia*, *Phaestoma* (*Puccinia Clarkiae*), *Chylisma*, *Godetia*, *Oenothera* (*Puccinia Oenotherae*), *Eulobus* (*Puccinia Eulobi*), *Sphaerostigma* (*Puccinia Sphaerostigmatis*) and *Zauchneria* (*Puccinia Zauchneriae*). This group of hosts possesses rusts with thicker walled and darker teliospores, as in the preceding race, but with the apical thickening often greater, $4-12\ \mu$, the thickening dark colored. The pedicel is sometimes up to $100\ \mu$ in length, the urediniospore walls thick. This race is correlated in particular with the *Uromyces Oenotherae* race of *Uromyces plumbarius*, although the *Uromyces plumbarius* and the *Uromyces Fremontii* races are not greatly different.

The above races of the species *Puccinia Epilobii-tetragoni* are not in all cases exactly correlated with the separate *Uromyces plumbarius* races, since no corresponding parallel of hosts, distribution, etc., fully

exists. The *Puccinia Oenothera* race differs from the *Uromyces Oenotherae* race only in the possession of two-celled teliospores. *Puccinia Epilobii-tetragoni* as a whole may well be said to be correlated with *Uromyces plumbarius* as a whole, as well as with *Puccinia Epilobii-Fleischeri*. The aecia in all three species are very similar to those of *Puccinia Veratri*. Possible correlations with short-cycled species of *Puccinia* are noted further with the discussion of such forms.

These races are separated out on morphological grounds, chiefly. Klebahn states (*l. c.*) that the biological identity of the forms upon different species of *Epilobium*, awaits proof; certainly the biological status of the collective species as here described, awaits study. The ultimate biological or physiological races may or may not follow these indicated morphological races; but it seems convenient at this time tentatively to designate such races.

Puccinia Krookii P. Henn., Ann. Naturhist. Hofmus. Wien for 1900: 1, described as on *Epilobium* sp., Harrysmith, Natal, and *Puccinia luxurians* Dietel & Neger, Engler's Jahrb. 24: 158. 1900, on *Oenothera mutica*, Cordillera de Santiago, Chile, present, in the descriptions, no distinctions that can be made use of in separating them from *Puccinia Epilobii-tetragoni* as here described. Both are listed in Sydow, Monog. Ured. Since no specimens are at hand for comparisons, however, their status cannot definitely be decided.

7. PUCCINIA VERATRI Duby Bot. Gall. 2: 890. 1830.

LITERATURE: Holway, N. Amer. Ured. 1: 21. 1905. Sydow, Monogr. Ured. 1: 639. 1903. Winter, in Rabenh. Krypt. Fl. 1: 184. 1881. Saccardo, Syll. Fung. 7: 665. 1888. Fischer, Beitr. Krypt. Schweiz 2^e: 81. 1904. Oudemans, Ann. Mycol. 2: 358. 1904. Tranzschel, Ann. Mycol. 7: 182. 1909. Klebahn, Krypt. Mark Brand. 5^a: 338. 1914.

O. Pycnia hypophyllous, scattered between the aecia, immersed, becoming brownish, globose or flask shaped, rather large, 112-144 μ in diameter by 128-175 μ in height; ostiolar filaments 55-65 μ long; pycniospores many, oval, 0.5-1 by 1-3 μ .

I. Aecia hypophyllous, numerous, crowded often over the entire lower surface of the leaf, broad cupulate, 0.3-0.6 mm. in diameter; peridium white, much recurved, the margin lacerate; peridial cells rhomboidal or oblong, 16-21 by 21-30 μ , somewhat overlapping, the outer wall 3-5 μ thick, striate, the inner wall 3-6 μ thick, verrucose; aeciospores roundish or oval, 14-18 by 16-24 μ ; wall light yellow, thin, 1 μ , finely verrucose.

ON ONAGRACEAE:

Chamaenerion latifolium (L.) Sweet (*Epilobium latifolium* L.), British Columbia.

Epilobium alpinum L., New Hampshire, Utah.

Epilobium Hornemanii Reich., Utah; British Columbia.

Epilobium paniculatum Nutt., Idaho; Washington.

Epilobium rubricaula Rydb., Utah.

II and III. Described in literature indicated.

Oudemans (*l. c.*) has clarified the situation in regard to the author of this name, Niessel being often given credit for the name. So, too, Sydow's use of the name *Puccinia Veratri* Duby as a synonym for *Uromyces Veratri* (DC.) Schroet., is in error.

Tranzschel (*l. c.*) established the connection of the form with uredinia and telia on *Veratrum* with these aecia on *Epilobium*, obtaining his clue from the similarity of teliospores of this species with those of *Puccinia Epilobii*. In America it had for some time been noted that aecia occurred upon *Epilobium* without being followed by telia. These aecia agreed in general with the aecia of *Puccinia Epilobii-tetragoni*, however; they were therefore usually referred to that species. Actual cultures have not been reported for America showing the connection with *Puccinia Veratri* in such cases, but it seems logical to assume that such aecia are the alternate phase of this *Puccinia Veratri*. As noted in the discussion of *Puccinia Epilobii-tetragoni*, differences in aecia referred to these two species are small indeed. The aecia can scarcely be considered to be local. In truth, it has been more upon the fact that telia did not follow aecia, telia upon *Veratrum* being at hand, or sometimes because of proximity of collections of the two forms, that led to the aecial specimens being considered to be *Puccinia Veratri*.

Descriptions of the aecia for this heteroecious species have not been found in the literature.

There is a foreign *Uromyces* on *Veratrum*, with smooth teliospores and thickened apex, evidently not correlated with *Puccinia Veratri*.

8. PUCCINIA PECKII (DeToni) Kellerman, Journ. Mycol. 8: 20. 1902.

O & I. Described as *Aecidium Oenotherae* by Peck in Rep. N. Y. State Mus. 23: 60. 1873. (See Sacc. Syll. Fung. 7: 790. 1888.)

II and III. On several species of *Carex*.

The aecia of this species have been found upon *Gaura*, *Onagra*, *Merolix* and *Pachylophus* from many parts of North America, especially from the central plains area. The aecia are distinguishable, especially from those of *Uromyces plumbarius*, which occur upon some

of the same hosts, by their local character. The aecia are rather large, the aeciospores up to $21\ \mu$ in diameter, with thin walls.

This species is shortly to be discussed in some detail by Kern.

As is indicated later in this article, the teliospores of this species, upon Carices, resemble the teliospores of certain other rusts upon the Onagraceae.

9. PUCCINIA JUSSIAEAE Speg., Anal. Soc. Cienc. Argentina 12: 68. 1881.

(*Puccinia Ludwigiae* (Ell. & Ev.) Holway, N. Amer. Ured. 1: 72. 1907.)

LITERATURE: Ell. & Ev., Proc. Acad. Phila. 155. 1893. Ell. & Ev., Bull. Torrey Club 22: 363. 1895. Saccardo, Syll. Fung. 14: 298. 1899; 21: 627. 1912. (See also below.) Sydow, Monogr. Ured. 1: 438. 1903. Spegazzini, references below.

Ellis and Everhart in 1895 described this Puccinia as on *Nesaea verticillata*, which was an error for *Ludwigia polycarpa*. (See Holway, l. c.) The name *Puccinia Nesaeae* was used, and perpetuated by Saccardo and Sydow. Ellis and Everhart had previously (1893), however, described the aecial stage of this fungus as *Aecidium Ludwigiae*.

This rust occurs upon various species of *Ludwigia* (*Isnardia*) in the central and southeastern portions of the United States.

With this species, formerly known as *Puccinia Ludwigiae*, is placed *Aecidium Jussiaeae* Speg. and *Puccinia Jussiei* Speg., making the name for this species *Puccinia Jussiaeae*. C. R. Orton, in working upon *Puccinia Ludwigiae*, discovered that the above rusts upon *Jussiaea* agree exactly, so far as can at present be determined, with the *Ludwigia* rust. Furthermore, Spegazzini states that the *Aecidium* is found associated with the *Puccinia* stage upon *Jussiaea*, thus making the rust one with the same life cycle as *Puccinia Ludwigiae*. Also, according to Engler and Prantl, *Jussiaea* and *Ludwigia* are very closely related and similar plants. *Aecidium Jussiaeae* was described in Anal. Soc. Cienc. Argentina 9: 174. 1880; also in Saccardo, Syll. Fung. 7: 790. 1888, and distributed by Spegazzini as Dec. Myc. Argentinae 30. This specimen is in the herbarium here. *Puccinia Jussiei* was described in Anal. Soc. Cienc. Argentina 12: 68. 1881; then in Sacc. Syll. Fung. 7: 700. 1888. The hosts given are *Jussiaea lanceolata* and *Jussiaea longifolia*. No specimens of this *Puccinia* are at hand, but the description agrees almost exactly with that of *Puccinia Ludwigiae*.

To Mr. Orton are also due thanks for finding that *Aecidium Isnardia* Lagerh. Tromso Mus. Aarsh. 17: 102. 1895, described as upon leaves of *Isnardia* from Ohio, collector uncertain, belongs here. *Isnardia* is a synonym of *Ludwigia*. Farlow, Bibl. Index 1¹: 59. 1905, gives some further data regarding *Aecidium Isnardia*.

Puccinia Jussiaeae Speg., being the oldest name for this species, is, therefore, to be used.

This species, with long, narrow teliospores, does not show a correlation with *Puccinia Epilobii-tetragoni*. It is more definitely correlated with *Puccinia Circaeae*, as is discussed under the short-cycled species, in this paper.

10. PUCCINIA EPILOBII-FLEISCHERI Ed. Fischer, Bull. Herb. Boiss. 1897: 394. 1897.

LITERATURE: Saccardo, Syll. Fung. 14: 299. 1899. Sydow, Monogr. Ured. 1: 426. 1903. Fischer, Beitr. Krypt. Schweiz 2²: 154-155. 1904.

This species, known only from Europe upon *Epilobium Fleischeri* Hochst. (*Chamaenerion Fleischeri* Fritsch.) is without a uredinial stage. As Fischer (*l. c.*) states, it is nearly related to *Puccinia Epilobii-tetragoni*, excepting in the lack of uredinia. Fischer notes some small differences in the telial stages of the two species; yet this is no doubt correlated with *Puccinia Epilobii-tetragoni*, as previously indicated.

It seems to be established that uredinia do not occur in *Puccinia Epilobii-Fleischeri*; Fischer lists several collections bearing aecia and telia together. It is worthy of note that this species occurs at high altitudes, *i. e.*, in Switzerland. As already noted, uredinia of *Puccinia Epilobii-tetragoni* often occur less abundantly at higher altitudes in western North America. While no host-species of *Epilobium* has been found there which conspicuously lacks in the development of the uredinial stage, and while the evidence of the fixity of such a character in America is lacking, it is to be expected that a form agreeing with *Puccinia Epilobii-Fleischeri* may be found in the higher western portions of our continent.

Cultures have, apparently, not yet been made to decide just what the life cycle is in *Puccinia Epilobii-Fleischeri* under various conditions.

The short-cycled species of *Puccinia* upon the members of the Onagraceae present some difficulties. This is more directly due to the

fact that, of these forms, only *Puccinia Circaeae* has been collected in America in sufficient numbers to render its status definite. There is a considerable variation, in the morphological characters, between these different short-cycled forms. These characters appear to indicate evident relationships or correlations with different long-cycled species of rust upon the same or similar hosts. As is indicated under each species, and discussed further on in this article, these short-cycled forms appear to fall into two, very doubtfully three, general groups: the first, represented by *Puccinia Circaeae*, *Puccinia gigantea*, and *Puccinia Fuchsiae*, shows resemblance to *Puccinia Jussiaeae*. The second group, represented by *Puccinia Epilobii* and *Puccinia scandica*, shows a relationship to *Puccinia Veratri* and to *Puccinia Epilobii-tetragoni*. The third, represented by *Puccinia sphaeroidea*, is distinctive, but evidently does not in reality belong among the rusts of the Onagraceae.

II. PUCCINIA CIRCAEAE Pers. Tent. Disp. Fung. 39. 1797.

LITERATURE: Saccardo, Syll. Fung. 7: 686. 1888. Schroeter, Pilz. Schl. 1: 348. 1889. Sydow, Monogr. Ured. 1: 422. 1903. Fischer, Beitr. Krypt. Schweiz 2²: 319. 1904. Holway, N. Amer. Ured. 1: 79. 1907. Klebahn, Krypt. Mark Brand. 5^a: 552. 1914.

This cosmopolitan species occurs upon all the species of *Circaea* present in North America, the rust probably being coextensive with the host. It frequently has been noted that the teliospores germinate both as a micro- and a lepto-*Puccinia*, depending upon the season.

The teliospores in this species are shorter and narrower than those of *Puccinia Jussiaeae*, yet it would seem that these are correlated species. The micro-form bears a greater resemblance to *Puccinia Jussiaeae* than does the lepto-form.

Schweinitz, Schr. Nat. Ges. Leipzig 1: 70. 1822, listed *Uredo Circaeae* as occurring in Carolina, then in Trans. Amer. Phil. Soc. n. ser. 4: 291. 1832, gave the name as *Caeoma Uredo Onagrarum* Link, and Pennsylvania also as a locality. The names he gives are now considered to refer to *Pucciniastrum Circaeae*, a species which does not occur, so far as is known, in North America. In both the above mentioned publications Schweinitz also lists *Puccinia Circaeae*. Further information is being sought from the Schweinitz herbarium in Philadelphia; until an examination of the original material is made, if such a thing be possible, it may not be unreasonable to assume that

the somewhat different appearance of this rust in the micro- and leptiform, may have led to the supposition that an *Uredo* occurred upon *Circaea*.

12. *PUCCINIA GIGANTEA* Karst., Mycol. Fenn. 4: 42. 1878.

LITERATURE: Saccardo, Syll. Fung. 7: 669. 1888. Ellis & Everhart, Bull. Torrey Club 27: 60. 1900. Sydow, Monogr. Ured. 1: 428. 1903. Fischer, Beitr. Krypt. Schweiz 2²: 320. 1904. Holway, N. Amer. Ured. 1: 74. 1907. Klebahn, Krypt. Mark Brand. 5^a: 553 (note). 1914.

Holway places with this species *Puccinia annulata* Ell. & Ev., both of which occur upon *Chamaenerion angustifolium* (L.) Schur. (*Epilobium angustifolium* L.). *Puccinia annulata* was described as possessing smaller teliospores, yet the two species no doubt go together, *Puccinia annulata* being but an American variation of the European *Puccinia gigantea*.

This species is not greatly different from *Puccinia Circaeae*, and appears to be correlated with *Puccinia Jussiaeae*. Only a very few collections are at hand, however.

13. *PUCCINIA FUCHSIAE* Sydow & Holway; Sydow, Ann. Mycol. 4: 30. 1906.

LITERATURE: Holway, N. Amer. Ured. 1: 79. 1907. Saccardo, Syll. Fung. 21: 627. 1912.

This species, as far as is known, has only been collected once, at Amecameca, Mexico. Sydow, *l. c.*, suggests that this species is much like *Puccinia Jussiaeae* from South America. It may, however, quite probably be a correlated short-cycled form. An examination of the original material discloses no very obvious difference from *Puccinia gigantea*. The host listed is *Fuchsia thymifolia*.

14. *PUCCINIA EPILOBII* DC., Fl. Fr. 6: 61. 1815.

LITERATURE: Schroeter, Pilze Schles. 1: 319. 1889. Sydow, Monogr. Ured. 1: 427. 1903. Saccardo, Syll. Fung. 17: 348. 1905. Holway, N. Amer. Ured. 1: 73. 1907. Bubak, Archiv. Naturw. Land. Boehmen 13: 148. 1908. Lind, Danish Fungi 318. 1913. Klebahn, Krypt. Mark Brand. 5^a: 337. 1914.

This species, upon several species of *Epilobium*, is rather common in Europe. In America only two specimens referred to this species are known to have been collected (Holway, *l. c.*). Lind points out that the mycelium is perennial in the subterranean portions of the

the hosts; sori are therefore scattered. The teliospores are verrucose, the walls usually uniformly 2μ thick. As previously indicated, Klebahn directed attention to the similarity of these teliospores to those of *Puccinia Veratri*. While this micro-form thus corresponds with the long-cycled *Puccinia Veratri*, the relation with *Puccinia Epilobii-tetragoni*, especially with some collections possessing less thickened apices, is evident. The correlations thus evidenced, belong, then, to both the second and third types as indicated early in this paper.

15. PUCCINIA SCANDICA Johans., Bot. Centralbl. **28**: 395. 1886.

LITERATURE: Saccardo, Syll. Fung. **7**: 680. 1888. Sydow, Monogr. Ured. **1**: 427. 1903. Holway, N. Amer. Ured. **1**: 73. 1907.

Specimens referred here have been collected a few times in North America. The chief difference from *Puccinia Epilobii* is in the smaller size of the teliospores, and the rather thicker apices, in collections considered to be *Puccinia scandica*. *Epilobium alpinum* and *Epilobium clavatum* are the hosts known in North America. *Epilobium alpinum* is also an American host for what is considered to be *Puccinia Epilobii*. While the differences between these two short-cycled rusts appear to hold for North America so far as the few collections are concerned, further collections may possibly indicate that these two species belong together. This species shows more definitely the correlation with *Puccinia Epilobii-tetragoni*, especially the race upon *Epilobium*, and may also be considered to be correlated with *Puccinia Veratri*.

16. UREDO OENOTHERICOLA Speg., Anal. Mus. Nac. B. Aires **19**: 318. 1909.

LITERATURE: Saccardo, Syll. Fung. **21**: 794. 1912. Spegazzini, Anal. Mus. Nac. B. Aires **23**: 32. 1912.

Spegazzini described this rust upon *Oenothera mollissima*, from South America. He refers again to it in his later publication cited. No specimens have been seen by the writer. No clues are evident from his description. What the significance is, of his statement "pedicello hyalino mox fatiscente ($40-50\mu$ lng. 5μ crss.) saepe suffultae," is a question. It is not impossible that this rust may be the uredinial stage of some previously noted rust upon *Oenothera*.

DOUBTFUL SPECIES

17. PUCCINIA SPHAEROIDEA P. Henn. Hedwigia 42: (107). 1903.

LITERATURE: Sydow, Monogr. Ured. 1: 890. 1904. Saccardo, Syll. Fung. 17: 348. 1905. Holway, N. Amer. Ured. 1: 72. 1907.

This species, cited as upon *Jussiaea* sp., Lower California, differs markedly from any other rust upon the Onagraceae. The collection by Purpus, 1902, is the only one known. The specimen represented in the herbarium here is very fragmentary. The teliospores are ovoid, the wall uniformly thick, the pedicel persistent, often inserted laterally. These teliospores exactly resemble those of *Puccinia sphaerospora* Sydow and Henn., the hosts of which are Asclepiadaceous plants. Sections of the material indicate that the host is quite likely in reality some Asclepiad. The characteristic spores point strikingly toward such a conclusion. On the whole, this species seems most doubtfully to belong with the Onagraceous rusts.

EXCLUDED SPECIES

PUCCINIA COLUMBENSIS Ell. & Ev. Proc. Acad. Phila. 1893: 153. 1893.

Stated to be upon *Oenothera biennis*. Holway, Journ. Mycol. 8: 171. 1902, points out that the host of this Puccinia is Troximom, not *Oenothera*. An *Aecidium* labeled as upon the same host, proved to be upon *Solidago mollis* and the rust is described by Arthur, Bull. Torrey Club 31: 7-8. 1904, as *Aecidium recedens*. See also Sydow, Monogr. Ured. 1: 869. 1904.

UROMYCES INTRICATUS Cooke, Grev. 7: 3. 1878.

Stated to be upon *Gayophytum ramosissimum*. The host, however, proves to be *Eriogonum*. See N. Amer. Fl. 7: 244-245. 1912.

During the progress of this study, Professor Jackson obtained from the phanerogamic herbarium of the Field Museum, Chicago, a specimen (on *Jussiaea* sp., marsh land near Ferry River, vicinity of Kingston, Jamaica, Sept. 11-12, 1906, N. L. Britton, No. 397) which bears a very few small uredinial sori. The urediniospores are ellipsoid, 19-23 by 26-29 μ , the walls golden-brown, 1-2 μ thick, moderately echinulate, with equatorial pores. The known *Jussiaea* rusts are not believed to have an uredinial stage, but some Onagraceous rust, as for instance *Uromyces plumbarius*, may possibly occur upon *Jussiaea*.

The material is so scanty and the uncertainty so great, however, that one can only direct attention to this point.

As is to be expected, several genera of the Onagraceae are not known to be attacked by rusts. No other species of rust, than those herein listed, appear at present to be known to occur upon the Onagraceae.

As is stated in the beginning of this paper, the Sydows list 27 species of rust upon the Onagraceae, and 4 additional species occur in North America. Furthermore, the Sydows have not yet published the species *Aecidium Jussiaeae*, *Aecidium Circaeae*, and *Uredo oenothericola*. These 34 species are accounted for in this article under 17 titles. The arguments for this halving of the number of species are presented wherever a union is involved. Furthermore, a few other species are suggested as being of doubtful validity, notably numbers 16 and 17. It is suggested that the two races exist under the title *Pucciniastrum pustulatum* as herein treated.

Cultural data is necessarily of importance in limiting species and races; such data is at hand for but few of these rusts. The writer submits the foregoing arrangement of species, based upon a consideration of morphological characters and life histories, as well as hosts, distribution, and such limited cultural data as is at hand, in the hope that a workable arrangement may be presented. Finality of placement, is, of course, at the present time impossible.

The Onagraceae rusts, as far as the evidence in hand can be analyzed by the writer, appear, as partially indicated heretofore, to fall into three fairly definite groups, with an uncertain fourth group. (See the diagram.) The first is that of the *Pucciniastrums*, with the alternate stage, insofar as cultures have been successful, upon *Abies*. The morphological characters of the uredinial and telial stages upon Onagraceous hosts, are very similar within the different species of *Pucciniastrum*. They, however, can scarcely be construed to hint at any relation with the uredinial or telial stages of others of these rusts upon the same or similar hosts.

Following the suggestion of Dietel¹⁰ that the Uredinales have developed during geologic times with their hosts, the *Pucciniastrums* would be the oldest of these rusts, since their aecial stage, so far as

¹⁰ Dietel, P., Centr. Bakt., etc. 12²: 218-234. 1904, and Hedwigia 48: 118-125. 1908.

is known, occurs upon Gymnosperms. The telial stage further suggests a more primitive condition, resembling the fern rusts, which Dietel considers to be the oldest rusts. The genera *Epilobium* and *Chamaenerion*, the hosts of these species of *Pucciniastrum*, might therefore be considered to be older genera of the Onagraceae. Other facts, as indicated elsewhere in this article, point to the same conclusion. It is further to be noted that these two hosts harbor more species of rust than any other genera of the Onagraceae, including two heteroecious species, two autoecious long-cycled species, one with and one without uredinia, and three short-cycled species.

The second group is that including the long-cycled species *Uromyces plumbarius* and *Puccinia Epilobii-tetragoni*, and also the heteroecious species with its aecia upon the Onagraceae, *Puccinia Veratri*, the European species without uredinia, *Puccinia Epilobii-Fleischeri*, and the short-cycled species *Puccinia Epilobii* and *Puccinia scandica*. The morphological resemblances between the several species is so close that it seems quite logical to infer a relationship.

Uromyces plumbarius and *Puccinia Epilobii-tetragoni* differ but little in morphological characters in all the spore forms, save for the occurrence of one-celled and two-celled teliospores respectively. In other respects, however, the correlation does not hold as it does between certain other parallel species of *Uromyces* and *Puccinia*, for here a different set of hosts is attacked by the two species in question, and the geographical range of *Uromyces plumbarius*, while largely including that of *Puccinia Epilobii-tetragoni*, extends far beyond it, the *Puccinia* species being, in North America, wholly western, the *Uromyces* extending over the greater part of the United States. It is a curious fact that, so far as is known, the same species of host is not attacked by the two rusts. Indeed, unless they may meet upon the genera *Oenothera*, different host genera are attacked, that is, different genera as now subdivided. Twelve genera of the Onagraceae are given as hosts for *Puccinia Epilobii-tetragoni*; and seven genera as hosts for *Uromyces plumbarius*; while related genera obviously occur in the two sets, yet all are different. While deductions must be vague, this fact would seem at least to indicate that a rather definite and distinct specialization has arisen within these two species of rust. It might be inferred further that this specialization has occurred in a somewhat different way in each species; in the *Puccinia*, over a larger number of host genera, but limited geographically, in North America, to the

west; in the *Uromyces*, over a greater area of North America, but limited to fewer hosts. *Uromyces plumbarius* also shows less variation than does *Puccinia Epilobii-tetragoni*; this is rather to be expected. An apparently complicating factor is that of the occurrence of this *Puccinia* upon various species of the genus *Epilobium* in some part of every continent, doubtfully excepting Africa. This is, however, in line with other relations of these rusts to the genus *Epilobium*, as is noted elsewhere. The variable American hosts are followed by variable rusts; this variability is further indicated by the fact that species of *Uromyces* occur only in America. Indirectly, it seems to the writer, the sharp difference in host genera attacked by the two above rusts reflects a considerable accuracy of taxonomic arrangement of hosts.

Puccinia luxurians and *Puccinia Krookii*, as stated, may be included with *Puccinia Epilobii-tetragoni*.

The relations of *Puccinia Veratri*, with aecia upon *Epilobium*, and of the other species of this group, has been indicated, and scarcely needs further comment. *Puccinia Veratri* has a more extended distribution than has *Puccinia Epilobii-tetragoni*. What conclusions are to be drawn from the comparatively greater frequency, but more limited distribution, of *Puccinia Epilobii-tetragoni*, as compared with the evident rarity, yet, in America, broader distribution of the short-cycled *Puccinia Epilobii* and *Puccinia scandica*, the writer is not prepared to say.

Into the third group may be placed *Puccinia Jussiaeae*, *Puccinia Circaeae*, *Puccinia gigantea*, *Puccinia Fuchsiae*, and *Puccinia Peckii*. The teliospores in this group are easily distinguishable from those of the group mentioned in the preceding paragraphs, being longer and narrower, often paler. Here, too, this similarity exhibited is close enough through all the species of this group to suggest a relation. *Puccinia Peckii* bears the same relation to this group that *Puccinia Veratri* does to the preceding group. As *Puccinia Veratri* is more extensive in range, in North America, than is *Puccinia Epilobii-tetragoni*, so *Puccinia Peckii* has also a more extended range than has *Puccinia Jussiaeae*. The hosts of the two latter species are in no cases identical, in spite of an evident relationship. This third group lacks, as far as known, a representative with uredinia upon the Onagraceae. While, of the short-cycled species in this group, *Puccinia gigantea* and *Puccinia Fuchsiae* appear to be more rare, *Puccinia Circaeae* is common.


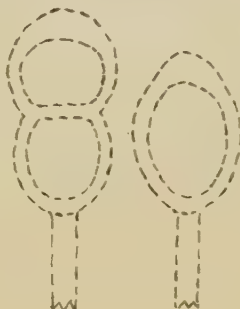

Into the fourth group must be placed the unknowns, *Aecidium Anograe*, *Aecidium Circaeae*, and *Uredo oenothericola*. (*Puccinia sphaeroidea*, as discussed previously, may be here omitted.) *Uredo oenothericola* may eventually land in the second group here given. Applying certain principles of correlation that have sometimes proven serviceable heretofore, one might vaguely prophesy regarding the alternate stages of *Aecidium Anograe* and *Aecidium Circaeae*. These two forms stand rather at extremes of the heteroecious aecial stages upon the Onagraceae. *Aecidium Anograe* has the largest aeciospores, and is the only one known possessing thick walls. *Aecidium Circaeae* has the smallest aeciospores, with thin walls. The former might be prophesied to go with an alternate form possessing rather large, thick-walled urediniospores; the latter, perhaps, with a form having small urediniospores.

Taking up the relation of these rusts to their hosts, a few points of interest are evident, in addition to those already presented in other connections. The related and cosmopolitan genera *Chamaenerion* and *Epilobium* harbor rusts that are placed in the first three groups just discussed. That there is some relation between the wide distribution, and, possibly, greater age of these genera, and the many, varied, and widely distributed rusts parasitic upon them, readily suggests itself. The most anomalous thing here appears to be the occurrence of the one representative of our third group, *i. e.*, *Puccinia gigantea*.

Another point with respect to hosts, rather out of harmony with expectations, is the conspicuous identity of the hosts of the different races of *Uromyces plumbarius* and those of the aecia of *Puccinia Peckii*. These two are not correlated species; and, indeed, as noted, neither of the two inhabits a host genus upon which an apparently correlated species does occur. The significance of this point seems perplexing to the writer.

Throughout these rusts upon the Onagraceae, wherever collections are in hand in sufficient numbers for a considerable comparison, variability is to be noted. Although short-cycled species are often found to be more constant, yet in the Onagraceae, the one American short-cycled species that is well represented in the Arthur herbarium has been found variable; it exists as a micro- or lepto-form in different seasons; the characters of the sori and teliospores vary. *Puccinia Jussiaeae* shows considerable variation. The marked variability of the autoecious species has been noted. One rather outstanding feature with

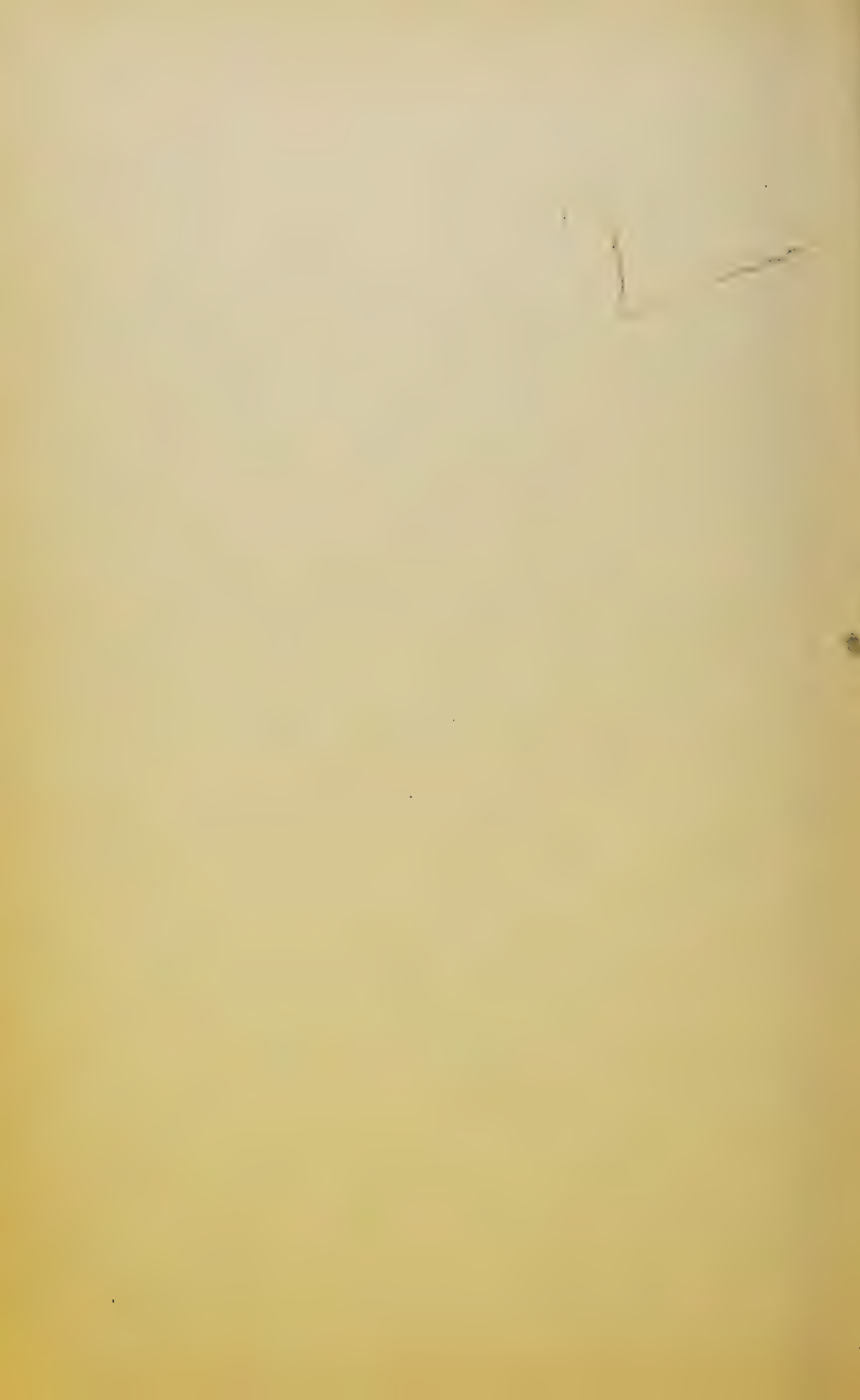
TABLE TO ILLUSTRATE THE GROUPS INTO WHICH THESE RUSTS FALL, WITH ALTERNATE HOSTS INDICATED WHERE KNOWN, AND DIAGRAMS OF THE GENERAL CHARACTER OF THE TELIOSPORES

1	2	3	4
Teliospores Adherent in Layers	Teliospores Free, Short-ellipsoid	Teliospores Free, Long-ellipsoid	
			(Probably Belong with Column 2 or 3, or Both)
II, III <i>Pucciniastrum pustulatum</i> (O and I unknown)	O, I, II, III <i>Uromyces plumbarius</i> <i>Puccinia Epilobii-tetragoni</i>	O, I, III <i>Puccinia Jussiaeae</i>	O, I <i>Aecidium Anograe</i> <i>Aecidium Circaeae</i>
(<i>P. Abieti-chamaenerii</i>) O and I on Abies)	(O), I, III <i>Puccinia Epilobii-Fleischeri</i>	(O), III <i>Puccinia Circaeae</i> <i>Puccinia gigantea</i> <i>Puccinia Fuchsiae</i>	
<i>Pucciniastrum Circaeae</i> (O and I unknown)	(O), III <i>Puccinia Epilobii</i> <i>Puccinia scandica</i>		II <i>Uredo oenothericola</i> (Other stages of the above unknown)
	O, I <i>Puccinia Veratri</i> (II and III on <i>Veratrum</i>)	O, I <i>Puccinia Peckii</i> (II and III on <i>Carex</i>)	

regard to the variability of these rusts is the comparative constancy, in spite of wide distribution, of the several rusts upon the related genera *Epilobium* and *Chamaenerion*. This fact, with others, it seems to the writer, indicates that the variability of the rusts upon the Onagraceae, as similarly noted by Dr. Arthur with the rusts upon the Rosaceae, reflects the variability of the hosts themselves. Indeed, the evolution of these hosts and their rusts would appear to present many parallelisms.

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Experimental Work on Potato Diseases at University Farm

G. R. Bisby,
Assistant Plant Pathologist,
University Farm, St. Paul, Minnesota.

All through the year, work with potatoes is carried on by the Section of Plant Pathology in the laboratory and greenhouses, and in the summer in the field also, with one aim; the better control of potato diseases. This may involve studies of the symptoms and of the causes of the diseases, since it is essential to understand these in order to apply control measures intelligently.

Specifically, the experiments consist especially of the following: (1) Spraying with Bordeaux Mixture. This spray has given excellent results at University Farm, being valuable not only as a preventative of potato blights, but also serving to increase yields when diseases are not serious. (2) Disinfectants, or seed treatments. The comparison of various substances that may be applied to seed potatoes to lessen scab, black scurf, etc. While corrosive sublimate and formaldehyde have proven valuable, there is hope also in other substances, particularly copper sulphate. (3) The value of crop rotation from the disease standpoint. (4) The value of seed selection and of seed plot methods. (5) Studies on potato tuber rots. (6) Studies on wilt, blackleg, 'rhizoetonia' diseases, etc.

The Section of Plant Pathology is always eager to help any grower with his disease problems, and is desirous of keeping in touch with conditions throughout the state.

Seed Potatoes and Potato Diseases.

G. R. BISBY, MINNESOTA EXPERIMENT STATION, ST. PAUL, MINN.

Everyone recognizes that diseases are highly important limiting factors in potato production, whether the acreage be large or small. I wish to point out some of the ways in which diseases can be avoided in seed potatoes.

Disease control is largely a matter of cultural practices. Mr. Baldwin has just pointed out an excellent method of securing healthy plants by sun-sprouting the potatoes indoors, and plant-



Showing effect of planting tubers produced under "dwarfed" vines. In every case but one the progeny was again dwarfed, and the yield small. At the right and left, normal plants.

ing only the tubers with vigorous sprouts. I wish to emphasize another method of developing vigorous, healthy potatoes, namely, the seed plot method, and to point out some of the considerations involved as shown by our experiments and by the experience of practical growers.

First, select or secure good seed from a good strain of a good variety of potatoes. There are standard varieties best suited to your own conditions; they should be determined upon and grown. There are variations in strains of the same variety; secure or build up a good strain of Early Ohios, Rurals or whatever variety is to be grown. The history, yield, etc., of the strain selected should be known; then the healthiest and best tubers selected, either by bin or field or hill selection, especially for the seed plot.

The seed should be treated. This, I believe, is especially

important this year, for much of the seed has black scurf, which may cause you trouble next year. Corrosive sublimate solution, four ounces to thirty gallons of water, for one and one-half hours, will kill the scurf and scab on your potatoes. Of course, it is true that the developing potatoes may become infected from the soil. We are working on possible treatments that will check soil infection, but the rotation of crops will reduce the amount of the disease in the soil.

The seed plot, and so far as possible the main field, should be one upon which potatoes have not been grown for three or more years. In our experimental plots we have found a decrease



Photograph taken Sept. 16, 1916, showing vines sprayed with Bordeaux at extreme right, unsprayed at left. Increase in yield, 38 bu. per acre.

of one-third after three years' continuous cropping with potatoes, due, at least largely, to the fact that disease germs have accumulated in the soil. Rotation of crops is very highly important from the disease standpoint.

Then the selected, treated potatoes, planted on a good soil plot, should be watched over as they grow. The large, vigorous plants should be encouraged, the weak, diseased plants destroyed, for in a comparatively short time they may contaminate the healthy. The undesirables, the mixed varieties, if any, the off types, the diseased plants, should be removed, root and branch, stem and tuber. And in removing diseased plants include not only those showing wilts and stem rots, but also those diseased because they are weak, dwarfed and unvigorous. I mention these dwarfed, unproductive plants particularly, because Dr. Melhus, of the Iowa Station, reported last year that some Minne-

sota seed produced weak plants in Iowa. We selected seed from dwarfed hills, which we found not uncommonly in Minnesota, and found in experimental plots at University Farm and in Clay County that seed from these hills gave only sixty per cent of the yield of seed of those plots from which these dwarfs had been removed, as follows: Ninety-four hills from seed dwarfed plants yielded 32.6 pounds of potatoes; ninety-four hills from seed from normal plants yielded 54.1 pounds of potatoes.

I have outlined briefly what I believe experience has shown to be the important things to do to keep up and improve your potatoes. I need not mention spraying for potato beetles, the necessity for cool, dry, clean storage. We are sometimes asked if spraying with Bordeaux mixture should be practiced, as you know it must be practiced in the northeastern portions of the country. We have carried on experiments for a number of years and found increased yield to result, even though late blight is not often serious in Minnesota. This year we obtained increases at the rate of eighteen to forty-six bushels of potatoes per acre, with three sprayings, depending on the strength of Bordeaux used. The accompanying table shows the results this year:

Treatment.	Variety.	Yield on 4 sq. rd.	Rate per acre.	Condition of foliage.
5-5-50	Early Ohio	240 lbs.	160 bu.	healthy
Bordeaux	Rural	193 lbs.	128.7 bu.	healthy
4-4-50	Early Ohio	204 lbs.	136 bu.	healthy
Bordeaux	Rural	174 lbs.	116 bu.	healthy
3-3-50	Early Ohio	193 lbs.	128.7 bu.	healthy
Bordeaux	Rural	183 lbs.	122 bu.	healthy
2-2-50	Early Ohio	198.5 lbs.	132.3 bu.	healthy
Bordeaux	Rural	163.5 lbs.	109 bu.	healthy
12-50	Early Ohio	212 lbs.	141.3 bu.	healthy
Tonicide	Rural	170.5 lbs.	113.7 bu.	healthy
2-50	Early Ohio	173 lbs.	115.3 bu.	died earlier
Lead Arsenate	Rural	145 lbs.	96.7 bu.	died earlier
1-50	Early Ohio	171 lbs.	114 bu.	died earlier
Paris green	Rural	140 lbs.	93.3 bu.	died earlier

Note—An early frost cut the yield, especially of Rural plots.

Under present conditions, before we are ready to make definite recommendations concerning spraying, we desire to carry on co-operative experiments with practical growers in various parts of the state. I rather believe spraying will pay, especially in intensive potato production, and perhaps we may be able to help those interested in trying it out.

By way of summary, the important things are these: Look away ahead; grow potatoes not only for this year's crop, but for the years to come. Select good seed. People have ceased raising runty cattle and hogs; it didn't pay. But runty potatoes

may leave their very germs in the soil to attack the vigorous potatoes one may try to grow later. Rotate crops, use a seed plot, treat the seed, remove undesirables. If one's strain of potatoes is declining or, as we say, running out a new strain should be secured, and the fight kept up for the vigor of the potato. For information on potato diseases, address the Section of Plant Pathology, University Farm, St. Paul.

Growing good, disease-free potatoes pays, for growing such seed is synonymous with good cultural practices.

Varieties of Vegetables Recommended for Minnesota Home Gardens.

(Taken from Society Folder for 1918).

- Asparagus—Colossal, Palmetto, Reading Giant.
- Bush Beans, Wax—Wardwell, Hodson, Pencil Pod.
- Bush Beans, Green—Bountiful, Refugee.
- Pole Beans, Green—Kentucky Wonder.
- Pole Beans, Shell—Horticultural.
- Beans, Lima—Dwarf preferable except in favored locations.
- Beets—Detroit, Eclipse, Egyptian.
- Cabbages, Early—Wakefield, Copenhagen.
- Cabbages, Late—All Seasons, Danish Ball or Holland.
- Carrots—Chantenay, Danvers Half Long.
- Cauliflower—Erfurt, Snowball.
- Celery, Early—Golden, White Plume.
- Celery, Late—Winter Queen, Giant Pascal.
- Celeriac—Erfurt.
- Corn, Sweet—Bantam, Crosby, Stowell Evergreen.
- Cucumbers—Boston and Chicago Pickling, White Spine.
- Egg Plant—N. Y. Spineless, Black Beauty.
- Endive—White and Green Curled.
- Horse Radish.
- Kale—Dwarf and Tall Curled Scotch.
- Kohl-Rabi—Vienna.
- Lettuce, Leaf—Grand Rapids, Black Seeded Simpson.
- Lettuce, Head—Big Boston, Hanson.
- Muskmelon—Gem, Osage, Montreal, White Japan.
- Onion—Red, Yellow and White Globe.
- Onion Sets—Any color or kind.
- Parsnip—Hollow Crown, Guernsey.
- Parsley—Moss Curled.
- Peas, Early—Alaska, Thomas Laxton, Marvel.
- Peas, Late—Telephone, Champion of England.
- Peppers—Bell, Ruby King, Cayenne.
- Potatoes—Early Ohio, Irish Cobbler, Triumph, King, Burbank, Burbank Russett, Green Mountain, Rural New Yorker.
- Pumpkins—Long or Round Pie.
- Radish—Scarlet Globe, Icicle.
- Radishes, Winter—Half Long and Round Black Spanish.
- Rhubarb—Victoria, Linnaeus.
- Rutabaga—Purple Top, Yellow Swede.
- Salsify—Sandwich Island.
- Spinach—Long Standing, Bloomsdale.
- Squash, Summer—Scallop, Crookneck.
- Squash, Winter—Marrow, Hubbard.
- Swiss Chard—Lucullus.
- Tomatoes, Early—Earliana, Bonny Best, John Baer.
- Tomatoes, Late—Stone.
- Turnips—Purple Top, Egg.
- Watermelons—Kleckley Sweet, Dark Icing, Tom Watson.

Destroy the Common Barberry.

E. M. FREEMAN, PLANT PATHOLOGIST, MINNESOTA EXPERIMENT STATION,
PRESIDENT, AMERICAN PHYTOPATHOLOGICAL SOCIETY.

The common barberry harbors, aids and abets the *black stem rust* of wheat and other grains. This has been proven without question. The indictment is against the common barberry (*Berberis vulgaris*), both the green and purple form. The Japanese barberry (*B. thunbergii*) is entirely innocent, and there is no necessity for its eradication. *Every common barberry in the state ought to be dug out, root and branch, and destroyed this spring before it has a chance to start the rust on the wheat.*



Barberry leaf with spots of wheat rust on it.

The common barberry is one of the chief factors in the stem rust of grains. In the spring the black stage on the wheat stubble and straw sends the little agents of infection into the air. These may fall upon a barberry leaf and start the rust on the barberry. The rust develops on the barberry from May to the middle of June, and the rust spores produced on the barberry are carried by the wind onto wheat and other cereals and upon a large number of wild grasses. A study of stem rust of cereals has shown that it is a complex problem, and that the weather and the wild grasses are also factors in any epidemic. But the more the problem is studied by experts along these lines, the more the experts become convinced that the barberry is one of the most important factors. The eradication of the barberry will certainly reduce the amount of rust. It will probably reduce it very con-

siderably and it may possibly completely control the rust. The value of the barberries in Minnesota is negligible compared with the value of the cereal crops, and this is especially true at this time when the production of a large crop of wheat and other cereals is of such vital national and world-wide importance.

Denmark dug out its barberries in 1903 and has had no stem rust of wheat since that time. North Dakota has dug out its barberries. Manitoba is digging out its barberries. The United States Department of Agriculture is putting on a large campaign to eradicate the barberries throughout the North Mississippi Valley, including Minnesota and all the neighboring states.

The University of Minnesota

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GROW BETTER POTATOES

STOP THE LEAKS IN CROP PRODUCTION

By A. G. Tolaas, Division of Agricultural Extension, and G. R. Bisby, Division of Plant Pathology and Botany

SELECTION OF SEED IN THE SPRING

Select potatoes that show vigor, health, and high yielding qualities. Superior strains have been developed in some varieties of potatoes as a result of careful selection; such strains show uniformity, vigor, and health. It does not pay to attempt to build up a poor strain by selection.

If the strain grown is unsatisfactory, get a better one. The past performance of a strain is a good indication as to what it will do in the future.

Do not introduce disease into the soil with the seed. Consider disease when selecting potatoes; treat the seed.

Discard, for seed, tubers showing rots or brown discolorations, either within the tuber or at the stem end. Such tubers, as well as knobby, irregular, "off shape," and very small tubers, can be eliminated in the process of sorting, racking, and cutting. It may not be practicable to select individual choice tubers for the general field, but this should be done for the seed plot.

TREATMENT

Tubers showing scab or black scurf on the surface should be treated with formaldehyde or corrosive sublimate. Treatment is valuable because it cleans the seed. Corrosive sublimate is ordinarily recommended, but on account of its high price this year, it may be advisable to restrict its use to potatoes for the seed plot, using formaldehyde for the general field.

Table I gives the results at University Farm summarized for three years, considering particularly black scurf (*Rhizoctonia*).

TABLE I. TREATMENT OF SEED POTATOES AND RESULTS OBTAINED AT UNIVERSITY FARM FOR THREE YEARS

Treatment	Strength	Time— Hours	Av. percentage of crop free from black scurf
Copper sulphate.....	3 pounds to 50 gallons water..	2	57.9
Corrosive sublimate....	4 ounces to 30 gallons water..	2	52.0
Formaldehyde solution..	1 pint to 30 gallons water..	2	45.9
Lime sulphur.....	1:40.....	2	37.7
Lime sulphur.....	1:30.....	2	26.5
Check, no treatment....	.....	..	23.1

Treatment with copper sulphate solution offers promise. It gave good results also as to yield. It is worthy of trial, altho it is desired to carry on

further experiments before recommending the solution for general use. It is hoped that copper sulphate treatment may lessen somewhat the danger of infection from the soil.

Barrels may conveniently be used for treating potatoes. Make holes near the bottom to draw off the solution when through treating.

Make formaldehyde solution by mixing one pint of formalin (40 per cent) with 30 gallons of water. Soak the seed in the mixture about two hours. The mixture may be used four or five times.

Make corrosive sublimate solution by mixing four ounces of the sublimate with 30 gallons of water. Dissolve first in a small quantity of hot water, then add it to the remainder of the water. Keep treated potatoes away from livestock, as corrosive sublimate is a deadly poison.

Do not allow tubers to come in contact with corrosive sublimate solution, for it injures them. Soak the seed for about an hour and a half. Use the solution three or four times.

Dry the potatoes after treatment. Seed potatoes are sometimes injured by being allowed to remain wet after treating. The seed may be cut at once and then allowed to dry, or the seed may be cut first, then treated, then allowed to dry or planted at once.

Use clean bins, sacks, baskets, or other containers to avoid contamination after the potatoes are treated or cut. The bin should be scrubbed out with a disinfectant (1 pint formalin to from 30 to 35 gallons of water; or copper sulphate solution, 1 pound to 30 gallons water.)

For small plots, sun-sprouted seed may be used, that is, plots that may be planted by hand. Seed potatoes are put where the sun or bright daylight will strike them until short, tough, green sprouts are formed, which come through the ground sooner. Discard tubers that do not show vigorous sprouts.

CUTTING

Cut the seed by hand. Discard diseased and undesirable tubers when cutting. To avoid spreading rots and other diseases with the cutting knife, two knives may be used, one kept in a solution of poison until a rotted tuber is cut into with the other.

Sulphur dusted over cut seed aids in drying the pieces and is of some value as a disinfectant. Put cut seed only in a clean bin; allow it to dry off sun; shovel it over; spread it thin. With careful handling, seed may be kept from one to three weeks after cutting.

ROTATION

Rotate crops. This is important, it avoids the accumulation of disease in the soil.

Potatoes grown on the same soil at University Farm for three successive years gave the following results:

Third year	.....	40% per cent germination, yield per square rod, 28 lbs.
In rotation	.....	40% per cent germination, yield per square rod, 41.8 lbs.

The decreased yield was largely due to diseases present in the soil.

A heavy plow, 18 in. in the rotation enriches the soil, and when plowed under lessens the danger from scab and other diseases.

CULTURAL PRACTISES

Plow deep for potatoes. The plants can not grow vigorously without plenty of loose soil. Do not, however, add more than an inch to the depth of plowing each year.

Do not plant too early. Cold, wet soil may cause the seed to rot.

Practice clean cultivation. More vigorous plants result. The absence of weeds means better air circulation and less danger from blights.

THE SEED PLOT .

Demonstrations carried on in Minnesota show the value of establishing and maintaining a seed plot. Table II shows what can be done by a little attention to seed selection and disease control.

TABLE II. RESULTS OF SEED SELECTION AND DISEASE CONTROL

County	Date	No. of plots	Average yield of plots per acre	Average yield of fields per acre	Average in- crease in yield per acre
			Bu.	Bu.	Bu.
Clay	1914	6	194	126.0	68.0
Clay	1915	10	130	86.0	44.0
Clay	1917	6	101	72.0	24.0
Hennepin	1915	9	192	162.5	28.5
Otter Tail	1916	9	118	95.0	23.0

Altho some of the individual differences were small, the tubers produced on the seed plots were in all cases of much better quality and more true to type and were less affected by disease.

Similar results can be obtained by establishing and maintaining a potato seed plot. Select a piece of ground in which potatoes have not been grown before. Select the seed to be used in this plot carefully with regard to type and freedom from disease.

By careful selection, control of diseases, and good cultural practices, and by growing varieties best suited to local conditions, an increase in yield of from twenty-five to fifty per cent, and a great improvement in quality may reasonably be expected.

Keep up the practice of growing a seed plot every year. It is preferable to select the seed for the seed plot at digging time because then the kind of stock the seed tubers come from is known. However, in order to get a start this year, bin selection must be resorted to. Select only sound tubers, true to varietal type, free from bruises and diseases, and weighing from six to eight ounces. If wilt was present in the field where the tubers were grown last year, cut off the stem end of every tuber to be planted in the seed plot, as this disease may be carried over in the tuber in the form of a brown ring discoloration. This precaution is necessary because there is no indication of the disease on the outside of the tuber.

Avoid using any tubers that show a tendency to "run out." It is a good policy to discard all such stock and to obtain seed from some grower who has a good, heavily producing strain of the desired variety. Treat the selected tubers in a solution of formaldehyde or corrosive sublimate as described under "Treatment."

Rogue the seed plot carefully at blossoming time. This means remove all undesirable plants, such as varietal mixtures, weak and diseased plants.

Spray the seed plot thoroly.

SPRAYING

Write to the State entomologist, University Farm, St. Paul, for Circular 47. Some Insects Injurious to the Potato, by S. A. Graham.

Spray with Paris Green, about 1 or 2 pounds to 50 gallons of water; or with lead arsenate, about 1½ pounds of powdered or 3 pounds of paste to 50 gallons of water, for beetles ("bugs").

Spray with Bordeaux mixture to avoid blight and to increase yield. The following results obtained for the last nine years show that spraying pays. The time of spraying is not so important as keeping some of the Bordeaux present on the leaves. In 1917, three thoro sprayings were given, July 20, August 9, and August 21.

1909-1915 results, total increase in yield per acre, bu.....	441.0
1916 results (2 sprayings)	
Early Ohio, increase per acre, bu.....	24.0
Rural New Yorker, increase per acre, bu.....	38.3
Average increase per acre, bu.....	31.1
1917 results (3 sprayings)	
Early Ohio, increase per acre, bu.	46.0
Rural New Yorker, increase per acre, bu.	35.4
Average increase per acre, bu.	40.7
Total increase, 1909 to 1917, bu.	512.8
Nine-year average annual increase per acre, bu.....	57.0

Neither 1916 nor 1917 was particularly favorable for potatoes, 1916 being hot and dry, and the early frost of 1917 cutting the yield of the sprayed plots, particularly by killing the vines prematurely, altho no late blight was present either year.

Spraying with Bordeaux mixture was beneficial. Bordeaux mixture having been shown to give the best results in spraying, tests of different strengths were made in 1917 to determine if a weaker solution would give good results in Minnesota. The results are given in Table III with "Tonicide," lead arsenate, and Paris green sprays as checks.

TABLE III. RESULTS OBTAINED FROM SPRAYING POTATOES WITH VARIOUS MIXTURES

Treatment	Average yield, early and late varieties, bu. per acre
5-5-50 Bordeaux mixture.....	144.4
4-4-50 Bordeaux mixture.....	126.0
3-3-50 Bordeaux mixture.....	125.4
2-2-50 Bordeaux mixture.....	115.7
12-50 Tonicide.....	127.5
2-50 Lead arsenate.....	106.0
1-50 Paris green.....	103.7

Bordeaux mixture prevents or lessens blights (early and late) and tip burn. Its use pays, even if disease is not present, for the leaves remain green and vigorous longer in the fall.

Make Bordeaux mixture from 5 pounds of copper sulphate, 5 pounds of lime, and 50 gallons of water. Dissolve the copper sulphate by hanging 5 pounds in a sack near the top of 25 gallons of water over night; slake the lime in a little water, and add enough to make 25 gallons; stir the two solutions, pour together, and use the same day. On a larger scale, use stock solutions.

Spray with Bordeaux about three times, beginning late in July or early in August. Use any sprayer that gives a high pressure and a fine spray.

Paris green or lead arsenate may be mixed with Bordeaux, if potato beetles are still prevalent.

SELECTION OF SEED

Select seed for next year's seed plot at digging time when the yield from each hill can be easily determined. This should be done by hand, only the tubers from high-producing vines being kept for the seed plot. After sufficient seed has been selected for next year's seed plot, the rest of the tubers should be kept for general planting. Avoid injuring or bruising the seed tubers in any way, as bruised potatoes are more likely to rot than sound ones.

STORAGE

Provide a cool, dry, well-ventilated cellar or storage house for potatoes. A warm, damp cellar furnishes good conditions for the development of rots. Keep the seed tubers for next year in separate bins. Keep the temperature as close to 35 or 40 degrees Fahrenheit as possible. A temperature above 40 degrees will cause the tubers to sprout too early, and cause considerable injury to the seed, by the loss of sprouts when handling them.

AN ANNOTATED TRANSLATION OF THE PART OF
SCHWEINITZ'S TWO PAPERS¹ GIVING THE
RUSTS OF NORTH AMERICA.

BY J. C. ARTHUR AND G. R. BISBY.

(Read April 13, 1917.)

Lewis David von Schweinitz was elected to membership in the American Philosophical Society in 1817, one hundred years ago. He was at the time a resident of Salem, North Carolina, a talented man of forceful character, secretary of the Moravian Missions of North America, and with one important botanical work to his credit. In 1805 there had been published in Leipzig a volume describing the fungi about Niesky,² a town of Saxony (later of Prussia), being the joint product of teacher and pupil during Schweinitz's four years' college course. The plates of the volume, with more than a hundred figures, were drawn, engraved and colored by Schweinitz, and much of the text bears the impress of his labor and judgment.

After five years of college teaching subsequent to his graduation, and five additional years in the ministry, he returned to America as general agent of the Moravian church in the Southern States, and became the pioneer mycologist of the New World. He was the only mycologist in the United States who added materially to the literature of mycology during the half century following his recognition by the American Philosophical Society. His *magnus opus*, which was truly a colossal work for the times, no less a work than a systematic account of the known fungi of North America,

¹ The papers referred to are the following:

"Synopsis fungorum Carolinæ superioris secundum observationes," *Schriften Nat. Ges., Leipzig*, 1: 20-131. 1822. The rusts on pp. 65-75.

"Synopsis fungorum in America Boreali media degentium secundum observationes," *Trans. Amer. Phil. Soc.*, II, 4: 141-316. 1832. The rusts on pp. 208, 209, 290-297, 306-314.

² Albertini & Schweinitz, "Conspectus fungorum in Lusatiae superioris agro Niskiensi crescentium," pp. 376, pl. col. 12. Lipsiæ, 1805.

PROC. AMER. PHIL. SOC. LVII. M, JULY 16, 1918.

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with nearly 4,000 species and 250 genera, was presented to the scientific world through the *Transactions of the American Philosophical Society*, having been transmitted to the Society April 15, 1831, and issued in printed form about a year later. It is usually spoken of as a "Synopsis of North American Fungi" from the secondary title used at the top of the pages.

It seems, therefore, especially fitting that on the centennial anniversary of Schweinitz's election to membership, the Society should take cognizance of his eminent and invaluable services to science, encouraged and aided as they were by the Society's approval.

No second attempt has followed Schweinitz's effort to present a full survey of the fungous flora of North America until recently, when the "North American Flora," to include all classes of plants from the highest to the lowest, was projected and supported by the New York Botanical Garden. In this work the fungi are to occupy ten or more imperial octavo volumes, and the text is to be supplied by many specialists. One volume is to contain the Uredinales, or rusts, and its preparation has been intrusted to the senior writer of this article, aided by the junior writer and other mycologists. In pursuance of this work it has become necessary to know definitely the extent of the contribution to the subject made by Schweinitz, an amount so considerable in fact that his name is encountered by the systematic student of the American rusts in much the same way that the name of Linnæus is encountered by the student of the flowering plants. The result of the detailed examination of the specimens in the Schweinitz herbarium, now deposited with the Academy of Natural Sciences of Philadelphia, and the interpretation of his published account in the light of this study of his original material, are presented to the Society in the following annotated translation from the Latin into English of that portion of Schweinitz's works pertaining to the rusts.

In Schweinitz's day the rusts were not recognized as a distinctive and sharply defined group of fungi, as they now are, but were to some extent classed with other fungi occurring on living or languishing hosts. They are all of microscopic size, but usually produce some characteristic discoloration or hypertrophy of the substratum, which aids in making them noticeable. In a few instances these

changes in the host amount to conspicuous alterations that attract the casual observer, as in the case of "cedar apples," and all the more so because the distortions are often accompanied by brilliant coloration.

For the study of these small objects Schweinitz was dependent upon lenses of poor definition and no considerable magnification. His chief instrument was undoubtedly the pretentious one now in the possession of his grandson, the eminent oculist of Philadelphia, Dr. Geo. de Schweinitz.³ This is still in almost or quite as good condition as when purchased probably some time prior to 1817. It was evidently one of the best instruments to be had at that period. As was pointed out in an early paper pertaining to the rusts, the first published on the subject by the senior author,⁴ a magnification of dry spores amounting to seventy-five diameters will give an appearance answering to the most detailed parts of Schweinitz's diagnoses. It is considered by Shear & Stevens,⁵ who kindly loaned to the writers during the preparation of this paper copies of their manuscripts embodying results of researches pertaining to Schweinitz's scientific labors and collections, that Schweinitz had to deal with a greater handicap than low magnification in his microscopic work. They find that the lack of spherical and chromatic correction of the lenses and the poor illumination must have resulted in decidedly inferior definition.

But in many cases it is clear that Schweinitz drew up the descriptions of his new species without making use of this instrument. He doubtless had some form of hand lens, although considerable inquiry has failed to reveal any present trace of such a glass. Even a simple hand lens seems not to have been used at times, and in general much dependence was placed upon the gross appearance and the changes wrought in the host.

It would be interesting to know what facilities in the way of books were possessed by Schweinitz. Probably his botanical

³ The instrument was kindly loaned by Dr. de Schweinitz for display before the Society at the presentation of this paper, and is illustrated by Shear and Stevens in *Mycologia* for July, 1917.

⁴ Arthur, "The Interpretation of Schweinitzian and Other Early Descriptions," *Amer. Nat.*, 17: 77-78, Jan., 1883.

⁵ *Mycologia*, 9: 195, 1917.

library was not large, but what works it contained can only be inferred. There are no records of books having been given to the Academy of Natural Sciences of Philadelphia or to the American Philosophical Society, and no such books are now in possession of his descendants. In a letter to the senior author, dated December 2, 1916, the Rev. Dr. Paul de Schweinitz, secretary of missions of the Moravian Church now living at Bethlehem, Pa., says that his grandfather who died in 1834 "left four sons, the oldest of whom [Emil] was only eighteen. The presumption would naturally be that when his widow died twenty-four years afterward [in 1858] his [botanical] books would have been divided among the sons, but I do not recall seeing any in my father's library. My father [Robert] was the last of his four sons to die." The widow of the third son, Mrs. Edmund de Schweinitz, is still living in Philadelphia and graciously received Dr. C. L. Shear and the senior author on the evening of February 5, 1917, but did not recall having ever seen any of Schweinitz's botanical books.

It is probable that the current works of Pursh, Michaux, Nuttall, Darlington, Bartram, Torrey, Barton, Muhlenberg, and other American botanists of the time were at his disposal in studying the flowering plants. Of these doubtless Barton's "Flora of Philadelphia" (1818), but above all Muhlenberg's "Catalogue" (1813, 2d edition in 1818) and Torrey's writings were in constant use. Although Amos Eaton, of Yale College, published a "Manual of Botany" in 1818, with successive editions until 1840, it does not appear to have been his guide in matters of nomenclature.

There were no American works on fungi at the time Schweinitz was most active in preparing his important contributions. Naturally he brought to this country the knowledge and many of the books which had aided in making the "Conspectus of Fungi about Niesky," prepared by himself and his teacher, Albertini, a work of standard value. In that work, as well as in the Carolina list he followed Persoon very closely as his model, and did not think it advisable to attempt any marked deviation from what he considered an authoritative nomenclature and systematic arrangement. In 1825 Link's treatment of the Hyphomycetes and Gymnomycetes for Willdenow's edition of the "Species Plantarum" became available, and received Schweinitz's full indorsement.

Among the innovations introduced by Link and adopted by Schweinitz in his later work was the use of the genus *Cæoma* to include what had before passed under the genera *Uredo*, *Æcidium*, *Peridermium*, etc. These older genera were only half ingested, however, and a sort of double generic name was made, that is, the genus and subgenus were used together: it was *Cæoma* (*Uredo*), *Cæoma* (*Æcidium*), etc. But this proved too clumsy for general use, and we find Schweinitz constantly reverting to the older nomenclature in his comments, as under 2887, *Cæoma* (*Æcidium*) *luminatum*, he speaks of "this *Æcidium*," not of this *Cæoma*, or of this *Cæoma* (*Æcidium*). Link's genus *Cæoma* never found much support, and eventually fell into disuse, although the older application of the name as a genus coördinate with *Uredo*, *Æcidium*, etc., is still in favor, these names in the most modern usage constituting form-genera. In the list of species placed by Schweinitz at the end of the volume, as those first detected by him in America, he lists *Æcidium*, *Ceratites* and *Peridermium* with initial rank, each with *Cæoma* as subgenus, leaving *Cæoma* as a genus to include only the one subgenus, *Uredo*, thus indicating some revolt, or at least inclination to deviate from Link's method. That the form of name given in the final list was no careless indexing but the conclusion of mature judgment seems certain from the use of one of these names in the description of 2932, *P. investita*, where he speaks of "*Æcidium gnaphalitatum*," the name in the final list, and not of *Cæoma Gnaphalitatum*, as given in the body of the work under 2873.

Another unfortunate innovation by Link faithfully adopted by Schweinitz was the change of specific names having the form of a proper noun, usually in the genitive singular, to the form of an adjective. Thus *Æcidium Galii* became *Cæoma galiatum*, *A. Berberidis* became *C. berberidatum*, *A. Violæ* became *C. violatum*, and so on for a dozen or so well-known names, and to this list Schweinitz added many more, *i. e.*, *Cæoma pyrolatum*, *C. hepaticatum*, *C. myricatum*, *C. dracontionatum*, *C. houstoniatum*, *C. pedatatum*, *C. clematitatum*, *C. helianthatum*, *C. trachelifoliatum* and eighteen or twenty more, all of them again listed under "*Æcidium* (*Cæoma*)" at the end of the volume. These changes with few exceptions were made under the genus *Cæoma*. Link changed a few specific proper

names under the genus *Puccinia* from the singular to the plural, thus *P. Galii* became *P. Galiorum*, *P. Pruni-spinosæ* became *P. Prunorum*, *P. Violæ* became *P. Violarum*, etc., and in this was imitated to some extent by Schweinitz as in the change of *Puccinia Helianthi* to *P. Helianthorum*.

All these changes were with the clear intent of making the name more accurately and fully represent the facts pertaining to the species. It was an attempt to carry out the idea that still persisted from pre-Linnæan times, that the name should embody some characteristics of the thing named, and in so far as a binomial name permitted, be descriptive. It was logical, consequently, to bring the name down to date, and upon ascertaining that the rust on *Prunus* was not confined to one species of *Prunus*, as at first supposed, but occurred on more than one, to change the name from *Puccinia Pruni-spinosæ* to *P. Prunorum*, and similarly so for other cases. The same result was even better attained by using a generalized adjective form for the specific name. It must be borne in mind that DeCandolle's dictum that the first name given to a species was the only legitimate name and should not be changed because found to be inappropriate had only been stated in 1813, and had received no general adherence, certainly not by German authors.

Along with the belief in descriptive names went the prevalent idea of the nature of species. Species were treated as concepts. This accounts for Schweinitz's insistence that when Link transfers one of Schweinitz's species to another genus and also changes the specific name in accordance with reasons just stated, or any other, it is Schweinitz and not Link who should be cited for the new form of the name. Schweinitz established *Æcidium Caladii*, and Link changed the name to *Cæoma* (*Æcidium*) *aroidatum*, yet Schweinitz places his initials after the latter name to indicate that it is his species (*i. e.*, his concept), and not Link's species. And so it comes that the names first published by Link, *Cæoma luminatum*, *Puccinia aculeata*, *Podisoma macropus*, and many others, founded upon Schweinitz's earlier descriptions of species differently named, are followed by the initials of Schweinitz in his later work.

The collection of Schweinitz's fungi at his death in 1834, was left to the Academy of Natural Sciences of Philadelphia. Each

specimen was preserved in a paper packet, made by folding over the sides of a sheet of paper until they touched or somewhat overlapped, then folding over the ends in the same manner and in the same direction. On the back of the packet an autographic record was made in ink. When a change was necessitated in the label by the adoption of Link's nomenclature, or for other reasons, in many cases the packet was not discarded, but refolded inside out and the data replaced in the new form on the back. This conservative practice, doubtless adopted merely as a convenience in handling, has given a chronological record that has often proved of much value when studying the original material, as showing changes in Schweinitz's views regarding the best form of the name or the identity of the material. The packets were of no uniformity in size, but varied from about three by six centimeters or smaller up to six by ten centimeters, and a few still larger.

Some thirty or forty of these packets were placed loosely in large envelopes, folded in a similar manner to 22 by 38 centimeters from heavy steel-blue paper, and a list of the species inclosed written on the back. Three to five of these envelopes according to bulk were put into a pasteboard portfolio of the same size and seven or eight centimeters in thickness, and tied with tape, the back being lettered with the consecutive number and the genus represented. The whole collection was contained in 39 portfolios, making a series of shelf volumes in outward appearance resembling a set of the modern bound fungi exsiccati. All the fungi were placed in one series, the European, North American and Surinam specimens being intermixed.

The part of Schweinitz's work on North American Fungi with which this paper has to deal is with the exception of eight species comprised under the two genera *Cæoma* and *Puccinia*. The material under *Cæoma*, both American and European, occupies the five envelopes in portfolio no. 38, and embraces 243 packets, of which considerably more than half are now empty. The material under *Puccinia* occupies two of the envelopes in portfolio no. 39, and embraces 84 packets, more than half being empty. Altogether under *Cæoma* and *Puccinia* 178 collections are European, 130 being without specimens, 18 are from Surinam, 3 without specimens, and

131 are North American, 60 without specimens, making a total of 327 packets, of which 193 are empty.

So far as the North American material in the portfolios is concerned, it is only the surplus after a suitable part had been removed for mounting. The Schweinitz collections representing his work on the North American Fungi, were mounted by Dr. Ezra Michener mostly during the years 1856 and 1857. As pointed out by Shear & Stevens (*Mycologia*, 9:337. 1917) the packages of fungi and the mounting material were sent by the Academy of Natural Sciences of Philadelphia to Dr. Michener, the work being done at his home in New Garden, Pa. Even at that time some of the packets were empty, as in a letter to Rev. M. A. Curtis Dr. Michener says: "I have been grieved to find a number of the envelopes either missing or empty." They were doubtless essentially in the same condition when they came into the possession of the Academy some twenty years before. From a letter written to Dr. John Torrey by Schweinitz shortly after his return from Europe in 1819 we learn that he had taken a full set of specimens illustrating his new species together with a list of his American fungi abroad with him and left them with Dr. Schwägerichen at Leipzig. This was the North Carolina list printed not long afterward at Leipzig under the editorship of Dr. Schwägerichen. It is not known whether or not these specimens are yet in existence. Taking out this set may have nearly or quite exhausted his supply in some instances. Specimens were also sent to no less than fourteen individuals and herbaria according to Shear & Stevens,⁶ among them being his correspondents at Upsala, Kew, Edinburgh, Paris, Berlin, Vienna and elsewhere, which doubtless drew heavily upon his material at times.

So far as concerns the part of the collections examined by the writers it seems that Schweinitz was usually in the habit of making but a single collection to represent a species and when he observed the same species in another locality he merely added the new locality on the outside of the packet. In a few cases he preserved collections, made by himself or sent to him by others, illustrating different hosts, as of 2826 *Cæoma* (*Uredo*) *Solidaginis*. Occasionally he appears to have replenished an exhausted packet by a later

⁶ *Mycologia*, 9: 333, 1917.

collection as under 2930 *Puccinia Asteris*, the packet says "on *Aster paniculatus*" but contains only material on *A. cordifolius*. In rare instances he may have placed a second collection of what he believed to be the same form in a packet still having some of the original collection. In most cases, however, the specimens now to be found in the packets appear to represent Schweinitz's first American collection of that form. And so it comes around that when a species had first been found in North Carolina and subsequently found in Pennsylvania or elsewhere the material preserved to represent it generally is the North Carolina collection. This is a most fortunate situation, as the specimen is thus the type for the earlier of Schweinitz's names, when a change was made in the latter work. The present priority rules require the use of the earliest specific name which in the present connection is a name usually much to be preferred for its brevity and aptness.

The fungi from North America in the portfolios as presented by Schweinitz to the Philadelphia Academy were labelled in accordance with his work on North American Fungi, and in large part constituted the basis for that work. Under the genera *Cæoma* and *Puccinia* only one North American specimen occurs not mentioned in his published account. It is labelled "*Æcidium Dircatatum* Ind.," and must have been collected upon his visit to Hope, Indiana, where he went to organize a church. This was in the summer of 1831 and doubtless too late to have the name placed in his manuscript. The packet contains three leaves of *Dirca*, 5 by 7.5 cm., 4 by 8.5 cm., and 5 by 6 cm., the last with part of each end removed, each leaf bearing a single small group of æcia.

Besides the specimens which Schweinitz carried abroad, and those sent to his European correspondents as mentioned above, many were sent to his American correspondents, and especially to his intimate friend, Dr. Torrey. The last were finally given by Torrey either to Curtis and are now in the Herb. Curtis at Harvard University, or to Berkeley, and are now in the Kew Herbarium. After the collection came into possession of the Philadelphia Academy portions of specimens were removed by Curtis for purpose of study during a seventeen-day visit in 1851 (Shear & Stevens, *Mycologia*, 9:335), part of which were transmitted to Berkeley.

Not long afterward the Academy arranged with Dr. Michener to place the collection in a more secure and accessible form, Curtis having been largely instrumental in bringing this about.

In mounting the collection a representative portion, or all when the material was scanty, was taken from each packet and glued to uniform slips of white writing paper 8 by 10 cm., on which the number, name, and source were written as given in the North American Fungi (see cut under no. 2881). In some cases the material was placed in paper packets that were glued to the slips. These mounts were consecutively arranged by pinning them to the inner page of folded sheets of brown paper, and the sheets placed in heavy board portfolios. The portfolios, 12 altogether, are 26 by 36 cm. and tied with tape. There are 85 mounts under the genus *Caoma*, of which five are smuts, and some others belong to non-uredinalean species, as stated under the several numbers in the systematic account which follows. There are in addition 6 mounts representing rusts, two under *Sphæria*, one under *Sciridium*, one under *Gymnosporangium*, and two under *Podisuma*. The whole genus *Puccinia* is unrepresented.

When the senior author was preparing to make his first visit to the Academy for the purpose of examining some of the types in the Schweinitz collection, he learned from Mr. W. C. Stevenson, Jr. (in letter dated Oct. 19, 1898), a member of the Academy, that part of the mounted collection had disappeared. Few persons had been critically interested in rusts in the recent years, and it was easy to ascertain that none of them had knowledge of the whereabouts of the missing specimens. No one then belonging to the Academy could give any information. It was generally believed that the missing sheets would eventually be found in the herbarium rooms of the Academy. However, a subsequent search failed to bring the missing material to light. The researches of Shear & Stevens regarding the history of the Schweinitz fungi have shown quite conclusively (*Mycologia*, 9:340, 1917) that the material representing nos. 2905-2946 embracing *Puccinia* and some subsequent genera, was mounted by Michener and that the mounted part must have disappeared later. The original packets are still in their envelopes in the portfolios. Fortunately there is some ma-

terial of Schweinitz's forty-two numbers under *Puccinia* in the autographic packets and also in other herbaria. Dr. Farlow states that 32 of these numbers are represented in the Herb. Curtis at Harvard University and Dr. Shear writes that there are 37 in the Michener collection at Washington.

The senior author has consulted the part of the Schweinitz collection containing the rusts a number of times between 1899 and 1917, for a few hours or a few days each time, as other duties demanding a visit to Philadelphia or nearby cities permitted. The first visit of three hours' duration was on Feb. 17, 1899, and a second one of about the same length of time on Aug. 4, 1900. At this second visit the impossibility of satisfactorily deciding upon the identity of many of the collections without better microscopic facilities and more time than could be hoped for while in Philadelphia was forced into prominence. A bit from an ample specimen, such as would furnish a few spores for examination under the microscope, could be carried away when the need was great, without a feeling of having done harm to this precious historical collection, but many specimens were too meager for such liberties. About a score of specimens of the unmounted material were selected at this time which most needed study and a request left to have them sent to Lafayette, Indiana, for more careful examination. But the authorities of the Academy had become wary, their attention having been called recently to the mysterious hiatus in the mounted set, including the important genus *Puccinia*, and had decreed a general ban on all loans. It was not until 1915 that the regulations were so far modified that the privilege was obtained to study these specimens microscopically for a few days in April of that year at the laboratory in Lafayette.

During the four days of December 28-31, 1903, many hours were spent in consulting the collection, at which time the senior author was assisted by Dr. Frank D. Kern, and again much study was given the collection during the five days of December 28, 1914, to January 1, 1915, assisted by Dr. F. D. Fromme. The senior author also consulted the collection on February 5-12, and April 11-14, 1917, Dr. C. L. Shear being present part of the time during the April period and giving valuable assistance in interpreting the

data. A few hours of study were also given on other dates not now definitely in mind. In order to verify and complete the mass of information secured in this fragmentary manner the authorities of the Academy, upon presentation of the situation by Dr. Witmer Stone, the acting curator, most generously transmitted all of portfolio 38 and 39 of the original set, and the final portfolio of the mounted set. These were received in Lafayette, Ind., the latter part of April, 1917, and returned the latter part of February, 1918, in exactly the same condition as when received. Owing to this invaluable opportunity for verification it is believed that the statistics given in the following account are accurate within the limits of ordinary error.

It has been the privilege of the senior author to examine many collections of micro-fungi, and he can say advisedly that the Schweinitz collection shows great care in its labelling and arrangement, and considering the vicissitudes of practically a hundred years, in which the requirements of correspondents, the need of transmitting specimens for examination, the later consultations by visiting mycologists, the ravages of insects and the accidents incident to handling by attendants, is in a remarkably good state of preservation. The packets would have been somewhat more secure, if they had been folded after the modern manner by overlapping the edges more and folding the ends in the reverse direction from that of the sides. But as it is, there is little evidence that specimens have been lost out, or intermixed to any harmful extent. To insure further protection and facilitate examination in the future the senior author in February, 1917, after consultation with Dr. Shear⁷ and Dr. Witmer Stone, placed each packet still containing any material, found in the seven large gray envelopes marked *Cæoma* and *Puccinia*, whether American or foreign, into small manila envelopes and wrote the name on the front. Of the 140 numbers in the North American list under the genera *Cæoma* (exclusive of the subgenera *Albugo* and *Ustilago*), *Puccinia*, *Phragmidium*, *Podisoma* and *Gymnosporangium*, 103 are represented at this date by specimens in the

⁷ Dr. Shear, of the Bureau of Plant Industry, Washington, D. C., and the senior author are members of a committee from the American Phytopathological Society to give whatever assistance may be possible in the preservation of the Schweinitz Herbarium.

collection at Philadelphia, either in the original autographic packets or mounted. Of the additional species of rusts, two under the genus *Sphaeria* and two under *Seiridium*, there are three represented by specimens.

The careful and conscientious work of Schweinitz is further evident in the identification and naming of his material. This can be shown by examination of the species which Schweinitz considered to be new, and to which he attached his initials. In the North Carolina list there are 45 such species under the genera *Æcidium*, *Uredo* (exclusive of the subgenera *Albugo* and *Ustilago*), *Puccinia* and *Gymnosporangium*, and of these only one was wholly misunderstood, nine are still accepted under the full names given by Schweinitz, twenty-one still have the same specific name but are placed under other genera and fourteen only have the name wholly suppressed under synonymy. In the North American list there are 88 names followed by the initials of Schweinitz under the genera *Cæoma* (exclusive of the subgenera *Albugo* and *Ustilago*), *Puccinia*, *Phragmidium*, *Gymnosporangium* and *Podisoma*. Only four of these species were misunderstood and erroneously placed, while twelve are still accepted as named, twenty-four still retain their specific names under other genera, and forty-eight have the whole name relegated to synonymy. The discarding of over half of the new names found in the later work is largely due to Schweinitz's replacement of earlier names by others conforming to Link's new methods, as already explained, which made them untenable according to the present requirements of priority. The above showing is as good as can be found in most lists of rusts by recent mycologists, so rapid are the mutations in nomenclature of this group of fungi. In general it shows that Schweinitz made comparatively few mistakes in the identification of his material, and in naming tried very commendably to follow the most progressive and authoritative methods as then understood. At the present time the two or three dissimilar stages which many rusts exhibit are included under one name, while formerly they were placed under separate genera. This in large part accounts for the 125 numbers in Schweinitz's North American list, now known or believed to represent rusts, having shrunk to 90 species as at present classified.

The very large part of the material, which was the foundation of Schweinitz's two works, especially of the portions relating to the rusts, was secured by himself. He collected over a radius of thirty miles or so about Salem, North Carolina, and probably over even a wider radius about Bethlehem, Pennsylvania, the two localities in America where he resided. A very few collections were made upon his trips to more distant points, and some specimens were sent to him by his correspondents, especially by Torrey and Halsey, of New York, and Collins of Philadelphia, while a few were handed to him by friends whose names appear at times upon the packets, particularly Detwiler and Denke.

The earliest biographical account of Schweinitz is that by Walter R. Johnson, read before the Philadelphia Academy of Sciences, May 12, 1835, a little more than a year after his death. It has been the source of information for many later sketches, notably those by Morgan,⁸ Kellerman,⁹ Shear,¹⁰ Harshberger,¹¹ and Lloyd.¹² Other writers have added various facts, obtained from Schweinitz's descendants, especially Gore,¹³ Youmans,¹⁴ Lehman,¹⁵ and Shear & Stevens.¹⁶

The three articles by Shear & Stevens were the result of extended researches regarding the history of Schweinitz's collections of fungi, his methods of work, and the present disposition of his specimens. Manuscript copies of the last two papers, as well as the one on Ezra Michener (*Bull. Torrey Botanical Club*, 44: 547-558, Dec., 1917) by the same authors, were generously loaned to the writers while this article was in preparation. Most of the works of various kinds referred to by the several authors have also been at the disposal of the writers. They have also consulted the manu-

⁸ *Bot. Gaz.*, 9: 17-19, 1884.

⁹ *Jour. Myc.*, 2: 31-34, 1886.

¹⁰ *Plant World*, 5: 45-47, 1902.

¹¹ "The Botanists of Philadelphia," 127-132, 1899.

¹² *Mycological Notes*, No. 44, 1916.

¹³ *Jour. Elisha Mitchell Sci. Soc.*, 3: 9-25, 1886.

¹⁴ *Pop. Sci. Mo.*, 44: 833-840, 1894; and "Pioneers of Science in America," 167-175, 1896.

¹⁵ *The Wachocia Moravian*, 13¹⁴²: 4-6, 1904.

¹⁶ U. S. Dept. Agric. Bull. no. 380: 1-82, Jan., 1917; *Mycologia*, 9: 191-204, 333-344, July, Nov., 1917.

script works of Schweinitz and the letters (amounting to 237) from his correspondents deposited at the *Philadelphia Academy of Natural Sciences*, the letters from Schweinitz to Torrey (35 in number) at the New York Botanical Garden, and the letters from correspondents in the possession of his grandson, Dr. Geo. de Schweinitz, of Philadelphia.

Some of his biographers say that during the latter years of his life he used *de* in place of *von* in his name. It is quite certain that after his death his sons and their families used the French form of the name; as their descendants do at the present time. His correspondents addressed him variously. By German friends and many others the address used was *Herr von Schweinitz*, or by a few of them *Baron von Schweinitz*, while a less number used *de Schweinitz*. His intimate American friends, Torrey and Darling-ton, both of English descent, invariably used *von*. All of the Schweinitz letters to Torrey at the N. Y. Bot. Garden are signed *Lewis D. v. Schweinitz*; they extend from June 24, 1820, to May 2, 1832. His published writings bear this form of his name on their title pages, except when made to conform to the Latin. The initials invariably used on his packets of fungi and other collections were *LvS*. When used in print to indicate authorship they were written *L.v.S*. In the North Carolina list the abbreviation was *Sw*.

There were doubtless reasons why he might have favored a change in the family name, either out of consideration for his wife, who was of French ancestry, or because of his dislike to Prussia, which at the Congress of Vienna in 1815 had acquired a third of Saxony, including that part where the ancestral home was situated and where his youth had been passed. But it is quite probable that he himself did not adopt the new form.

The botanical work of Schweinitz was made the avocation of a busy life largely devoted to religious duties and churchly service. He was imbued, nevertheless, with the most thoroughly scientific spirit. His monographic work upon the very difficult genera, *Carex*, *Viola*, and *Spharia*, was of the highest order. He eschewed the easy assumptions too rife in his day, and believed that a scrutiny of facts outweighed all plausibilities. What may be designated as his scientific creed is given in the preface to the *Conspectus* by Albertini &

Schweinitz, which was doubtless written by Schweinitz. It refers especially to the study of fungi, and as translated by Johnson (Memoir, p. 25) reads:

"A solid basis to this department of botanical science must be laid, not on a sandy foundation, on the varying freaks and fancies of the mind, but on a perpetual daily and nightly employment of microscopic observation, a diligent and oft-repeated examination of the whole history of the fungous tribes, a careful perusal of authors, a comparison of their respective synonyms, and above all, by the observation of living nature herself, as she unfolds her rich abundance in the recesses of forests, lawns and marshes, an observation which must be continued from day to day, and from year to year."

The following account includes a translation of that portion of Schweinitz's two works pertaining to rusts, given in the order of the later one, together with a record of material still remaining to represent them, and with comments by the writers. It has been prepared with a view of making this monumental work more available to students, especially students of American mycology.

Following the main body of the work all of the species of rusts mentioned by Schweinitz are arranged in systematic order in accordance with present ideas of classification. The accepted names used for the hosts are generally those of Britton & Brown's "Illustrated Flora," 2d edition, or of Small's "Flora of the Southeastern United States," 2d edition.

A serial list is then given of all the numbers in Schweinitz's "North American Fungi" with which this account deals, with the corresponding numbers from the North Carolina list in parentheses, and in a parallel column the name or fact which the study of the material has disclosed. An index of hosts and another of fungi are appended for convenience of reference.

The microscopic and bibliographical work carried on in connection with this study of the Schweinitz material pertaining to rusts during the eighteen years since the work has been in progress has been done in large part at Lafayette, Ind., in the laboratories of the agricultural experiment station of Purdue University. More than a dozen of those associated in the laboratory work during this long period have taken part in the study, and to them, and to a number of correspondents credit is accorded for material aid. To the

authorities of the Philadelphia Academy of Sciences the gratitude of the authors and of every scientific person interested in this subject is due in unstinted measure. Under Mr. Stewardson Brown, Curator of the herbarium, and Dr. Witmer Stone during Mr. Brown's absence, every facility that the Academy could offer has been placed freely at the disposal of the authors.

RUSTS OF NORTH AMERICA RECORDED BY SCHWEINITZ.

The arrangement is that in Schweinitz's *Synopsis Fungorum in America Boreali*. Additions to the translation of the original text are in square brackets. The general serial number is followed by the species number under each genus. As stated by Schweinitz on page 144 of his work "species preceded by an asterisk are those not recorded in the '*Synopsis Fungorum Carolinæ Superioris*.' Species with L.v.S. added were first described by me either in my previous work or in the present one."

After the complete record for each number the corresponding record in his "*Synopsis Fungorum Carolinæ Superioris*," if there is one, is given in parentheses.

Following the English version of Schweinitz's words is a statement of the material to represent the number as it occurs in the Schweinitz Herbarium at the Philadelphia Academy of Sciences at the present time, the data on the packets being copied exactly as to spelling, capitals, punctuation, etc. Finally come comments by the authors.

1474. 329. *S[phæria] epiphylla*, L.v.S., Syn. Car. 130, F. 258, not in Pennsylvania.

(130. [*Sphæria*] *epiphylla* Sz.

S. cespitose, blackish brown, shining, the pulverulent receptacle yellowish, spherules without ostioles, obovate, very minute, crowded, arranged cespitosely or fasciculately.

It grows in an unusual place, namely, upon still growing leaves of *Galega virginica*. Scattered, on the upper surface of the leaves, punctiform, or oblong or linear, less than a line in diameter. Receptacle arising from the altered substance of the leaf, pulverulent, yellowish or brownish. Spherules globose, minute, obovate. At a younger stage subpellucid.)

Represented by two leaflets mounted, each about 2.5 cm. long,

and by the original packet, empty, labelled on the front "*Sphæria epiphylla* LvS . . . Salem . . ." a portion not being legible, and on the folded end "*Sphæria epiphylla* Salem."

While Dietel was making a study of the genus *Ravenelia*, he received a fragment of the original Schweinitz collection, sent by Lagerheim from the Herb. Fries, from which he was enabled to transfer the species to that genus (*Hedwigia*, 33:27. 1894), although he points out that the true nature of the fungus had already been detected (Farlow & Seymour, "Host Index," page 30. 1888). The name is now generally written *Ravenelia epiphylla* (Schw.) Diet.

- *1487. 342. *S[phæria] canaliculata*. L.v.S., of the same group [as the preceding species, 1486], but abundantly distinct. Bethlehem, on leaves of the involucre of *Cyperus*, found on the dorsal surface. S. covered, dark, composed of series of perithecia situated between the striæ of the leaves, parallelly confluent on a pitch black spot, so that the spot appears beautifully canaliculate; rather large. Ostioles thick, punctiform. On the margin occur subsolitary, subrotund, applanate perithecia. In the middle, moreover, the pitch black spots are sometimes sterile—and, it may be noted, the spot is frequently interrupted at intervals of a quarter of an inch, so that the unaltered substance of the leaf comes into view.

Represented by a mounted specimen, consisting of a portion of five leaves, originally six, one having become detached and lost, each portion about 5 cm. long and 6 or 8 mm. broad, well supplied with uncovered uredinia and covered telia. The original packet contains two small pieces of leaf, and is labelled "*Sph. canaliculata* LvS in *Scirpi* involucr." It was evidently first labelled "*Sph graminis*," as the word "*graminis*" has been crossed out.

The true character of this fungus was first pointed out by Lagerheim (*Tromsø Mus. Aarsh.*, 17:51. 1895), from the study of an original autographic specimen in the Fries Herbarium. It is now called *Puccinia canaliculata* (Schw.) Lagerh., and is a widespread American species.

*Species preceded by an asterisk are those not recorded in the "Synopsis Fungorum Carolinæ Superioris."

CLASS V. GYMNOAMYCETES (ENTOPHYTÆ and TUBERCULARINI Fries).

SERIES I. ENTOPHYTÆ.

Genus 211. CÆOMA.

α Subgenus UREDO.

1. *Ustilago*.

Note.—The six species under this heading nos. 2811 to 2816 are smuts belonging to the Ustilaginales, and are therefore omitted.

2. *Rubigines* (Orange-yellows).

2817. 7. C. U. *Rubigo*, Lk. n. 9. Halsey from New York, on cereals.

Represented by part of a leaf, 6 cm. long, mounted, and a similar piece of leaf, nearly as long, in the original packet, each about 1 cm. broad. The packet is labelled "*Uredo tecta* Halsey," and again later "*Cæoma rubigo* Newyork Halsey."

Both leaves appear to be those of wheat (*Triticum vulgare* Vill.), and are well covered with large, scattered, oblong uredinial sori.

The name was correctly applied by Schweinitz in the sense in which it was first employed by De Candolle and others of the times. It covers a number of species, however, and the one represented by the collection is *Puccinia graminis* Pers., in its uredinial stage, now usually called *P. poculiformis* (Jacq.) Wettst.

2818. 8. C. U. *linearis*, Lk. n. 8, Syn. Car. 464, on leaves of cereals, Salem, Bethlehem, and everywhere.

(464. 6. [*Uredo*] *linearis*. Fairly common on grain.)

Represented by portions of four narrowly linear leaves, each piece 8 to 10 cm. long, loose in a mounted packet, bearing a few scattered uredinial sori. The original packet is labelled inside "*Uredo linearis* Sal," and outside "*Cæoma* (*Ured*) *lineare* Salem."

The compound microscope easily shows the rust to be the uredinial stage of *Puccinia Poarum* Niessl now more often referred to *P. epiphylla* (L.) Wettst. It is characterized by peculiar capi-

tate paraphyses. The host is the common Kentucky blue-grass, *Poa pratensis* L. It is a species not found on other grasses or on grains, although uredinia of similar gross appearance are found on both, and were all given the same name by older mycologists. Probably the original portion of the material on cereals was removed by Schweinitz, leaving only the part on meadow grass.

*2819. 9. *C. U. rimosum*, Lk. n. 14, rather rare on *Scirpus* near Hope, New Jersey.

Represented by one 5 cm. mounted piece of a terete culm, and five similar pieces, 3 to 5 cm. long, in the original packet, which is labelled "*Cæoma* (Ured) *rimosum* in *Scirp* acut. spec. imperfecta ob bonas pertus. Hope Jersey." The host is undoubtedly *Scirpus lacustris* L. (*S. acutus* Muhl.), the plant that Schweinitz took it to be.

The smooth surfaces of the culms show a few quite regular rifts, 5–15 mm. long, but no spores or fungus of any kind. These rifts may have been interpreted by Schweinitz to be the "*acervis* in *rimis longitudinalibus parallelis positus*" of Link's description, for he has entered on his packet that he had an "imperfect specimen on account of marked perforations." Link's *Cæoma rimosum* was, however, founded upon a fungus on *Juncus acutus* from Egypt, and could not have been the same as an American fungus on *Scirpus*. Lagerheim in his study of the rusts in the Herb. Fries (l. c., page 67) has erroneously added "*Uredo rimosa* Schwein." as a synonym of *Puccinia obtecta* Peck, a rust that occurs on both *Scirpus pungens* (the host in the Herb. Fries from New York), having triangular stems, and *S. lacustris*, having terete stems. Had this rust been present Schweinitz would probably not have referred it to Link's species, because of the slight resemblance which it bears to Link's description.

*2820. 10. *C. U. Andropogi*, L.v.S., on leaves of *Andropogon avenaceum*, Bethlehem; rare and related to *C. longissimum*, from which it differs particularly by an evident purple spot.

C. spots much elongated, narrow, purple. Sori much elongated, parallel, narrowed, longitudinally erumpent from the raised epidermis. Spores at last loosely scattered, globose, rufo-fuscon.

Represented by parts of two leaves, about 5 cm. long, and of two others, 7 cm. long, all 5 to 8 mm. wide, mounted, and in the original packet five similar pieces with some fragments, all bearing an abundance of brown uredinia and a few telia. The packet is labelled inside "Cæoma (Ured) Rubigo Lk in Androp. avenacei fol Beth 1829," and outside "Cæoma (Ured) *Andropogi* LvS."

The host is evidently *Andropogon avenaceum* Michx., as stated, now often referred to *Sorghastrum nutans* (L.) Nash, and the rust proves to be *Puccinia virgata* Ellis & Ev., a species not at all related to *P. Andropogi* Schw., no. 2911.

*2821. 11. C. U. *Iridis*, L.v.S., frequent on withered leaves of *Iris virginica*, Bethlehem.

C. related to C. *Lilii*; spots yellowish, sori roundish oval, not circinate but scattered; at first covered with the epidermis, rather elevated. Spores numerous, somewhat pedicelled, fulvo-ferugineous, at length scattered. Spores never turn black as in C. *Lilii*.

Represented by two well-preserved pieces of leaves mounted, one being 1 by 6 cm., and the other 1.5 by 7 cm., and two pieces much eaten by insects, in the original packet, and all well covered with uredinia. The packet is labelled "*Puccinia Iridis* LvS Beth," with the word *Puccinia* crossed out and "Cæoma (Ur)" substituted. There is an empty duplicate packet labelled in a similar way.

The rust is a common one of both hemispheres for which the accepted name is *Puccinia Iridis* (DC.) Wallr. In America, east of the Rocky Mountains, only uredinia have been found. Although the host is called *Iris virginica*, a linear-leaved species, both because these leaves are especially wide, and because no rust is known on that species, the host must be *I. versicolor* L.

2822. 12. C. U. *Smilacis*, L.v.S., Syn. Car. 471, Link n. 22, and Bethlehem on leaves of *Smilax*.

(471. 13. [Uredo] *Smilacis* Sz.

U. peridia variably flexuose, minute, grouped, often concentric, dark brown, the spore-mass luteo-fuscous.

Frequent, on leaves of *Smilax rotundifolia*, seated on yellowish spots.)

Represented by one piece of leaf 3 by 4 cm., cut from a leaf of probably twice the size, and mounted. It is thickly covered with

uredinia. The empty, original packet is labelled inside "Uredo *Smilacis* S. rotundifol Sal," and outside "Cæoma (Ured) *Smilacis* LvS in *S. rotundifol* Salem."

The rust is the uredinial stage of *Puccinia Smilacis* Schw., no. 2916, very common in the southeastern states on various species of *Smilax*.

2823. 13. C. U. Labiatarum, Lk. n. 34. Syn. Car. [as] U. Clinopodii, 469, and Bethlehem on species of *Pycnanthemum*.

(469. 11. [Uredo] Clinopodii Sz.

U. orbicular, somewhat inflated, yellowish.

Frequent in autumn on the leaves of *Clinopodium incanum*.

Related to U. *Menthæ*.)

Represented only by an empty packet, which is labelled inside "Uredo Clinopodii In Pycnanth. Salem," and outside "Cæoma (Ur) *Pycnanthemum* LvS C. clinopodii Salem." Without doubt Schweinitz had the uredinia of *Puccinia Menthae* Pers., on *Koellia incana* (L.) Kuntze, of which the preceding names are synonyms. He accepted Link's disposition of his new species as a synonym under Link's name for all the common mint uredinia.

2824. 14. C. U. Ipomœæ, [L.v.S.] Syn. Car. 468, Lk. n. 38, not Pennsylvania.

(468. 10. [Uredo] Ipomœæ Sz.

U. rather small, sparse, not confluent, bright red.

Frequent on the lower surface [of leaves] of *Ipomœa triloba*.

Related to U. *Tussilaginis*.)

Represented by three cordate leaves, 3 cm. long, mounted, well covered beneath with uredinia and telia, and two smaller leaves attached to a slender stem, in the original packet, bearing a few sori. The packet is labelled inside "Uredo Convolvuli Salem," afterward "Ipomœæ" written above Convolvuli, and outside "Cæoma (Ur) *Ipomœa* LvS in *Ip. pandur*. Salem."

The rust is an excellent example of *Colcosporium Ipomœæ* (Schw.) Burr., showing uredinia and telia, and the host is doubtless *I. pandurata* L., which was at first confused by Schweinitz with the more southern species, *I. triloba*. Although Schweinitz incidentally omitted his initials as author of the specific name in accordance with his custom in other similar instances, L. v. S. should be added,

for while the combination with *Cæoma* was first made by Link, it was based entirely on Schweinitz's account in his Carolina list.

2825. 15. C. U. *Elephantopodis*, L.v.S., Syn. Car. 467, Lk. [n.] 54, only in Carolina.

(467. 9. [Uredo] *Elephantopodis* Sz.

. U. rather large, sori depressed, sparse, circular, bright yellow.

On leaves and stems of *Elephantopus tomentosus*, very frequent in the autumn. Related to U. *farinosa*. Older sori leave Peziza-like hollows in the leaf.)

Represented by a leaf, 4 by 7 cm., mounted, and also a fragment of leaf in the original packet, both showing uredinia. The packet is labelled inside "*Uredo Elephantopodis* Salem," and outside "*Cæoma* (Ur) *Elephantopodis* LvS Salem."

The rust is now called *Coleosporium Elephantopodis* (Schw.) Thüm. As indicated for the preceding number Schweinitz adds his name to the *Cæoma* combination as author of the species although the combination was first made by Link. This was in accord with the opinion then held that the author's name was attached to the species as a voucher for the concept as expressed by the original description and not for the technical formation of the name as applied to a particular specimen, according to present usage.

2826. 16. C. U. *Solidaginis*, L.v.S., Syn. Car. 472, common, and Pennsylvania.

(472. 14. [Uredo] *Solidaginis* Sz.

U. compact, closed, red, linear, sometimes long.

Very frequent, almost all large *Asters*, *Solidagos*, *Vernonias*; related to U. *pustulata*.)

Represented by four original packets, and mounted material from two of them. Two smooth lanceolate leaves, probably of *Solidago serotina* Ait., showing purple discolorations, are mounted, evidently taken from the empty packet marked "1 *Cæoma* (Ured) *Solidaginum* LvS in maculis purp." A duplicate packet, also empty, is labelled "2 *Cæoma* (Ured) *Solidagini* LvS." The other mount consists of about two thirds of a smooth, lanceolate leaf with entire margin, probably of *Solidago sempervirens*. It was doubtless taken from the empty packet labelled inside "*Uredo* (*Æcidium*) *ovale* Nyk Halsey," and outside "*Cæoma ovale* Halsey Nyk," with the

word "ovale" crossed out and "Solidaginis" substituted. Halsey was a correspondent living in New York. The fourth original packet is labelled inside "Uredo Solidaginis in Vernonia noveboracensis Beth," and outside "Cæoma (Ur) *Solidaginum* LvS Salem & Beth." The packet contains the larger part of four lanceolate leaves, each fragment about 18 mm. wide and 7 cm. long. Three of these leaves are yellowish and are doubtless *Solidago altissima*, and may have been obtained at Salem, the fourth is greenish with sparse, colorless hairs, and is doubtless *S. rugosa*, and may have been obtained at Bethlehem. The inclusion of *Vernonia* may after a time have been considered erroneous, and the leaves removed.

All the seven leaves representing this number show uredinia of *Coleosporium Solidaginis* (Schw.) Thüm., one of the commonest of rusts in the eastern states. The unusual abundance of material preserved to illustrate this number was doubtless due to its being encountered frequently in the fields on many hosts.

2827. 17. C. U. Terebinthinaceæ, L.v.S., Syn. Car. 473, not in Pennsylvania. (473. 15. [Uredo] Terebinthinaceæ Sz.

U. aggregated, almost solid, pustulate, closed, becoming indurated, orange red, rather large. Frequent on the lower surface of the very thick leaves of *Silphium terebinthinaceum*. Related to populina.

N. B. They [i. e. the Rubigos] occur on almost all autumnal plants of the class Syngeneses, as on *Helianthus*, *Aster*, *Solidago*, etc., etc. As to the Rubigos, which ones constitute distinct species, it is most difficult to decide.)

Represented only by an empty packet, labelled inside "Uredo *terebinthinaceæ* in Silph terebint Salem," and outside "Cæoma (Ur) *Silphii terebinthinaci* LvS. Salem."

The rust is undoubtedly *Coleosporium Terebinthinaceæ* (Schw.) Arth., and the host *Silphium terebinthinaceum* Jacq.

Schweinitz's observation that it is difficult to decide upon the systematic distinctions among orange-yellow uredinia remains largely true at the present day.

- *2828. 18. C. U. *Helianthi* L.v.S., rather rare on leaves of *H. giganteus*, Bethlehem.

- C. spots obscure. Sori clustered, naked, pulvinate, flavo-rubrous, at first rather solid, finally sprinkled with the minute orange red spores.

Represented by parts of two small, lanceolate leaves. The smaller one, about 4 cm. long, is mounted, and is doubtless *Helianthus giganteus* L. The other, about 7 cm. long, is half in the original packet, which is labelled "Cæoma (Ured) *Helianthi* LvS in *Helianth* gigant. Bet," and half mounted. It is possibly *H. strumosus* L. A similar leaf, 4 cm. long by 1 cm. broad, and evidently part of the latter collection, is in the Michener Collection at Washington, now belonging to the U. S. Department of Agriculture.

The leaves all show many telia and a few uredinia, of what is now called *Coleosporium Helianthi* (Schw.) Arth. It is not an abundant species, but is widespread.

- *2829. 19. C. U. *Anemonis*, L.v.S., on under surface of [leaves of] *Anemone quinquefolia*, Bethlehem, rare.

- C. spots yellowish, rather large, sori roundish, dilated, slightly elevated, spores pale.

Represented by a compound trifoliate leaf about 4 cm. broad and long, mounted, having plenty of pale round uredinial sori beneath. The original packet is labelled inside "Uredo anemonis," and in another place "Cæoma *Anemonis quinquefoliæ* Bethl," while outside it reads "Cæoma (Ur) *Anemonis quinquefo* LvS Detwyler Bethl H."

As no such rust has been collected since on the host named, there has been much speculation regarding its identity. Not until the senior author's recent visit to examine the Schweinitz material at the Philadelphia Academy did the solution of the enigma become evident. It was then noticed that this so-called *Anemone* leaf is sparsely sprinkled with long colorless hairs, which remind one of those on *Osmorrhiza*. Comparing this leaf with material for no. 2841 and no. 2851, which had previously been determined as *Osmorrhiza*, left no doubt that all were the same host. On this host occurs *Puccinia Pimpinellæ* (Str.) Mart. (*P. Osmorrhizæ* C. & P.), with the uredinia of which this material exactly agrees.

This instance illustrates the danger in collecting too small speci-

mens, mere fragments. The large decompound leaves of the tall growing *Osmorrhiza* could not be mistaken in the field for the little wind-flower, but the trifoliate tip of one of the large leaves when isolated might well be supposed to be the whole leaf of a small plant.

2830. 20. C. U. Campanularum, Lk. 44, on *C. amplexicaulis*, Syn. Car. 465, and Bethlehem.

(465. 7. [Uredo] *Campanulæ*. Rarely occurs on *Campanula perfoliata*.)

No specimen or packet is in the collection to represent this number. The host is one on which there is no other record of a rust, although a species of *Coleosporium* does occur on the closely related genus *Campanula* as now understood. It is highly probable, however, that Schweinitz had some fungus not a rust. The plant is now known as *Specularia perfoliata* (L.) A. DC. (*Campanula perfoliata* L., *C. amplexicaulis* Michx.).

2831. 21. C. U. Onagrarum, Lk. 32, Syn. Car. *Circææ*, 466, and Bethlehem.

(466. 8. [Uredo] *Circææ*. Here and there on the leaves of *Circæa Canadensis*.)

There is no material or packet at Philadelphia to represent this number, which is unfortunate, as no common rust exactly answers the requirements of the record. The names employed for the rust are of a European species, not known in America. *Uredo Circææ* was established by Albertini and Schweinitz in their work on the Lusatian fungi for the uredinia of what is now called *Pucciniastrum Circææ* (Schum.) Schröt. The only rust on *Circæa* in this country is *Puccinia Circææ* Pers., which is so very unlike the one just referred to that it seemingly could not have been mistaken for it. Although *P. Circææ* possesses no uredinia, yet the young telial sori are pale and in gross appearance might be so considered. The record in both publications appears to parallel the corresponding records of *P. Circææ* under no. 2938, and the most reasonable interpretation appears to be that Schweinitz mistook the young stage of *P. Circææ* Pers. for a *Uredo*.

2832. 22. *C. U. miniata*, Lk. 84, Syn. Car. 463, Salem and Bethlehem.
(463. 5. [*Uredo*] *miniata*. Frequent but only on *Rosa pauciflora*.)

Represented by a mounted rose leaf, 7 cm. long, consisting of five leaflets, and the original packet containing one smaller compound leaf and a number of leaflets, all similar. There are large, irregular sori on rachis and midribs and annular, pustulate sori on the blades, all æcia. The packet is labelled outside "*Cæoma* (Ur) *miniata* Salem," and added later "& Bethl & Herrnht." Herrnhut is the place where Schweinitz studied in Saxony.

The material apparently is that gathered at Salem, N. C., and the addition of two other localities to the packet indicated the collector's field observations, and not his actual addition to the collection. The host name of *Rosa pauciflora* is given in Muhlenberg's "Catalogue" as synonymous with *R. carolina* L., the name now in use, which is doubtless the species Schweinitz found the rust on. The rust proves to be the æcia of *Earlea speciosa* (Fries) Arth., formerly called *Phragmidium speciosum* Cooke. Telia of this species were placed by Schweinitz under the genus *Sciridium*, no. 3084. The species is not known in Europe, and the selection of Persoon's name, *Uredo miniata*, has proven unfit, although at the time the two forms could not well have been separated. The transfer of the species to the genus *Cæoma* was first done by Schweinitz, not by Link.

- *2833. 23. *C. U. ruborum*, Lk. 86, frequent, Bethlehem.

Represented by no mounted specimen, but by some ten leaflets in the original packet, which is labelled inside "*Cæoma ruborum*, *Uredo* (Rubigo) Rubi In Rub id horti mei fr Oct. 1824," and outside "*Cæoma* (Ur) Rubi Idæi Bethl in hort." The largest of the leaflets is about 6 by 7 cm., and all are pale tomentose beneath, with powdery groups of urediniospores here and there in the tomentum.

The host is doubtless the European red raspberry, *Rubus Idæus* L., then frequently planted in gardens, but now almost wholly replaced by the similar native form, *R. strigosus* Michx. The rust is the uredinial stage of *Kuehneola Uredinis* (Link) Arth., a common species on various raspberries and blackberries, but whose affinities have only been recognized within the last few years. The telial

stage is white, and the name, *Phragmidium albidum*, is often applied. Link's name of *Cæoma ruborum* belongs to another rust.

2834. 24. C. U. *Potentillarum*, Lk. 87, Syn. Car. 461, frequent on *Potentilla canadensis*, [and in] Pennsylvania.

(461. 3. [Uredo] *Alchemillæ*. I am certain it is the same as that on *Alchemilla*. Here and there on the leaves of *Potentilla canadensis*, living through the winter.)

Represented by a mounted packet containing loosely a bit of stem and five leaves of the host mentioned. Three of the smaller leaves show primary uredinia above, and two larger leaves show secondary uredinia beneath, the sori being numerous. An empty original packet is labelled "*Cæoma* (Ur) *Potentillæ canadensis* LvS Sal & Beth."

It was quite natural for Schweinitz to think this rust was a form of *Uredo Alchemillæ*, both from the gross appearance of the leaves and of the sori on them, and to follow Link in placing it under the inclusive name, *C. Potentillarum*. The rust is now known to be wholly different, and is called *Frommea obtusa* (Strauss) Arth., or more commonly, *Phragmidium Potentillæ-canadensis* Diet., or *Kuehneola obtusa* (Str.) Arth.

2835. 25. C. U. *Agrimoniæ* L.v.S., usually wholly covering the lower surface of *Agrimonia*, wrongly [referred] to U. *Rosæ*, Syn. Car. 462.

C. spots becoming yellowish. Sori minute, confluent, spores beautifully reddish orange, finally losing their color.

(462. 4. [Uredo] *Rosæ*. I do not doubt that it is the same as occurs very frequently on *Agrimonia Eupatoria* in autumn; never on roses with us.)

Represented by three terminal leaflets, mounted, each nearly 4 cm. long, and by fragments of three compound leaves in the original packet, which is labelled "*Cæoma* (Ur) *Agrimoniæ* LvS Salem." All of the leaflets are abundantly covered with sori.

The rust is the characteristic uredinial stage of *Pucciniastrum Agrimoniæ* (Schw.) Tranz., which occurs in Europe and Asia, but not so common there as in America. The host appears to be *Agrimonia parviflora* Soland.

- *2836. 26. C. U. Filicum, Lk. n. 101, on *Aspidium*, from New York, communicated by Dr. Torrey.

Represented by about 4 cm. of the terminal part of a frond, mounted, and by parts of one or more fronds of uniform appearance in the original packet, which is labelled "*Cæoma Filicum* Torrey Nyk in Asp. obtus," and in addition "U. polymorph in Asp. dryopt.," with a number of German localities and names of German collectors. Probably the additions to the inscription on the packet do not indicate collections, but only memoranda.

The rust occurs in rather large, covered, blistery sori, on the under surface of the fronds, and is the uredinial stage of *Hyalopsora Aspidiotus* (Peck) Magn. The host is evidently *Phegopteris Dryopteris* (L.) Fée, the *Aspidium obtusum* of Muhlenberg's "Catalogue," and the collection was probably made in the Catskill mountains, as Dr. Torrey lived for a time at West Point, N. Y. The rust is not known outside of North America. It is a mountainous form, the type collection being found by Peck in the Catskill mountains.

- *2837. 27. C. U. Teucii, L.v.S., very rare on leaves of *Teucrium virginicum*, Bethlehem.

C. spots obsolete. Sori densely crowded into semblance of a spot, effused, beautifully red. Spores very small, very red, almost scarlet.

Represented by one leaf, oblong, 3.5 by 7 cm., mounted, and by the empty packet, labelled inside "*Uredo Teucii* in fol *Teucii canadens*. Salem," and outside "*Cæoma* (Ured) *Teucii* LvS. Naz." The leaf shows a number of rusty-looking spots, still finely purplish red, which the microscope reveals to be due to a Hyphomycetous fungus, having small oblong to linear-oblong spores, and in nowise related to the rusts, of which there are none known on *Teucrium* in America.

This material has been examined by Dr. C. L. Shear, who states that it is identical with *Cercospora racemosa* E. & M., a species founded upon a collection made by the senior author in Iowa, September 27, 1882. It is a somewhat common fungus extending from the Atlantic coast to Kansas and Nebraska. The name should be-

come, in accordance with the rules of priority, *Cercospora Teucriti* (Schw.) comb. nov.

2838. 28. C. U. *Azaleæ*, L.v.S., Syn. Car., 470, [as U.] *minima*, frequent on leaves of *Azalea nudiflora*, Bethlehem and Salem.

C. spots obsolete. Sori on the lower surface, at first somewhat cone shaped, minute, orange, finally effused. Spores very minute, losing their color, and unequal, pyriform, with globose forms intermixed.

(470. 12. [Uredo] *minima* Sz.

U. very minute, punctiform, pale orange, sparse, peridia subconic.

Frequent on the lower surface of the leaves of *Azalea nudiflora*.)

Represented by a mounted leaf 2 by 6 cm., thickly covered on the lower surface with uredinia corresponding to the description, and by an empty packet labelled inside "*Uredo farinosa* β *minima* in *Azalea nudiflora* Salem," together with the later name "*Cæoma minimum*," written above, and on the outside "*Cæoma* (Ur) *Azaleæ* L.v.S. Beth & Sal."

The rust is the uredinial stage of *Pucciniastrum minimum* (Schw.) Arth., as reported in the "North American Flora" 7:109. 1907, a name now believed to be synonymous with *P. Myrtilli* (Schum.) Arth., a rust occurring upon various species of *Vaccinium*, as well as on *Azalea nudiflora* L., and other Ericaceous hosts.

3. *Fuscentes and Nigredines* (Browns and Blacks).

2839. 29. C. U. *Ari virginici*, L.v.S., Syn. Car., [as U.] *Caladii*, 480, Lk. n. 21. It is not *Caladium* but *Arum* on which this is frequently found and in Pennsylvania.

(480. 22. [Uredo] *Caladii* Sz.

U. punctiform, solitary, seated on large yellowish spots, the spore-mass fuscous.

Frequent on the under side of the leaves of *Caladium*. Peridia at first closed, at length scattering the spores.)

Represented by a 3 cm. square portion, cut from a large leaf, mounted, showing uredinia scattered over the surface, and by an empty packet labelled inside "*Uredo Caladii* Salem," and outside "*Cæoma Ari virginici* L.v.S. n. *Caladii* Salem."

The rust is the uredinial stage of *Uromyces Caladii* (Schw.) Farl., the æcial stage being given under nos. 2860 and 2861, and the telial stage under no. 2946. Doubtless Schweinitz was right in thinking the host to be *Arum virginicum* L., now known as *Peltandra virginica* (L.) Kunth, and not *Caladium* [*sagittifolium* Nutt.], although the fact can not now be verified. Both hosts occur in North Carolina, but only the former in Pennsylvania.

2840. 30. C. U. *Spermacoces* L.v.S., Syn. Car., [under] *Puccinia*, 502, Lk. n. 57, elegant. Spores not septate, and Philadelphia.

(502. 17. [*Puccinia*] *Spermacoces* Sz.

P. subquadrate, dark chestnut-brown, spores globose, simple, pedicel very long, filiform.

Frequent on leaves and stems of *Spermacoce*. Breaks through the epidermis in the form of a square. Spores fuscous, irregularly globose, pointed or blunt, without septum. Pedicel ten times longer, hyaline. By pressure the epidermis is separated from the square mass as a continuous membrane in which a cellular structure is not to be seen under lenses having a focus of half a line, and a very thin vesicular substance escapes.)

Represented by two small fragments of stem with leaves and fruit, placed loose in a mounted packet. The original empty packet is labelled inside "*Dicæoma Spermacocis* Salem," and on the outside "*Cæoma Spermacocis* LvS. Sal."

The rust is chiefly the telial stage of *Uromyces Spermacoces* (Schw.) M. A. Curt., common throughout the southern states, and the host is undoubtedly *Diodia teres* Walt. (*Spermacoce diodina* Michx.).

It is interesting to trace the change in view, in the interim between the publication of the two papers, regarding the systematic position of forms with dark teliospores, which we would now call *Uromyces*. In the North Carolina paper of 1822 Schweinitz divided the genus *Puccinia* into "*A*, spores distinctly bilocular," and "*B*, spores globose with septum inconspicuous," evidently following the example of DeCandolle in the *Flore Francaise* (2: 224) of 1805. Under the latter division Schweinitz placed two species of *Uromyces*, with the septum described as absent or not conspicuous, respectively. Evidently there was a feeling that these forms with an uncertain septum and globoid spore belonged with those species of

Puccinia having elongated spores and an evident septum. Later the idea of a possible septum was abandoned, and it was necessary to place these dark, globoid, non-septate forms under the all-inclusive genus *Uredo*, in spite of their apparent relationship to *Puccinia*. Still later systematists placed them in the genus *Uromyces*, but recently the opinion has been growing that the earlier method of DeCandolle and Schweinitz better indicates their true relationship.

The mention of the kind of lens used in these studies helps to explain why the question of the presence of a septum should have remained uncertain. Even without knowing the degree of definition, doubtless far less than that of modern hand lenses, it is clear that the magnification left much to be desired.

*2841. 31. C. U. *Chærophylli*, L.v.S., on leaves of *Chærophyllum* or *Myrrhis Claytoni*, Pennsylvania.

C. spots obsolete: sori rounded, sparse and aggregated, even somewhat confluent, finally uncovered by rupturing the epidermis. Spores effused, globose, from tobacco-like to black, shining.

Represented by a compound leaf of three leaflets, each about 3 cm. long, mounted, showing uredinia and telia, and an empty packet, labelled inside "*Uredo chærophylli*, N. Beth Detwyler," and outside "*Cæoma* (Ur) *chærophylli* LvS prope Beth Detwyler."

The rust proves to be *Puccinia Pimpinellæ* (Str.) Mart. (*P. Osmorrhizæ* C. & P.), and the host to be *Osmorrhiza*, in all probability *O. Claytoni* (Michx.) Clarke (*Myrrhis Claytoni* Michx.), as suggested by Schweinitz. The material is essentially identical with that of nos. 2829 and 2851.

*2842. 32. C. U. *Hyperici*, L.v.S., on stems of an unidentified *Hypericum* rare in Carolina; not the same with *C. hypericorum*, Lk.

C. spots on the pilose-strigose stem, purple: sori sparse, acuminate-ovate, bullate, elevated, surrounded by the ruptured epidermis. Spores fuscous purple, becoming effused.

Represented by a much branched stem, without leaves, but with eleven seed pods, mounted, having uredinia sparingly distributed over the stem, and by an empty packet labelled "*Cæoma* (Ur) *Hyperici* LvS. Salem."

The rust is the uredinial stage of *Uromyces Hyperici-frondosi* (Schw.) Arth., and the host is some species of *Hypericum*, not yet identified, but which doubtless can be. Schweinitz was right in thinking his material quite different from *Cæoma hypericorum* Link, which belongs under the genus *Melampsora*.

2843. 33. C. U. *Heucherae*, L.v.S., Lk. 79, Syn. Car. 479, not in Pennsylvania. (479. 21. [Uredo] *Heucherae* Sz.

U. seated on orbicular, yellowish spots, peridia subconcentric, crowded, dark chestnut brown, spore mass dark fuscous.

Here and there on the leaves of *Heuchera Americana* and *villosa*. Peridia at first closed; at length scattering the spores, minute. Related to U. *Anemones*.)

Represented by part, about 4 by 5 cm., of a large leaf, mounted, having small, hypophyllous, pulvinate, brown sori, and by an empty packet labelled inside "Uredo *Tiarellæ Heucherae* Salem," and on outside "*Cæoma* (Ur) *Heucherae* Lvs. Salem."

The spores are oblong, two-celled, and smooth whether examined wet or dry. The rust is now called *Puccinia Heucherae* (Schw.) Dietel. The mounted leaf appears to be that of *Heuchera americana* L., but the rust is known to occur on many species, and may well have been seen by Schweinitz on *H. villosa* Michx.

The systematic position of the species must have been determined by Schweinitz from the gross appearance alone. This would account for its inclusion in the subgenus *Uredo*, and for the omission of spore characters in the description.

- *2844. 34. C. U. *apiculosum*, Lk. [n. not] p. 90, on *Phaseolus*, Bethlehem, Syn. Car. 478.
(478. 20. [Uredo] *flosculosorum*. Conspect. fung. On *Kuhnia*, *Eupatorium*, and other composites. (*Cæomurus* Link.))

No specimen or packet remains to represent this number. Two typographical errors occur in the entry. The asterisk should be omitted, and the reference to Link's work should read n. 90, and not "p. 90," the reference being to the number of the species and not to the page.

The name *Uredo flosculosorum* was established by Albertini and Schweinitz (Consp. Fung. Nisk. 128) and they named as hosts

Prenanthes, *Leontodon* and *Hieracium*, all Cichoriaceous composites, while here Schweinitz has extended the use of the name to Carduaceous composites, and even legumes. Link at the place cited reduced this name to a synonym, together with twenty-two others, under his inclusive species, *C. apiculosum*. The species has no value in the modern sense, being a concept supported only by superficial characters, and represented by an incongruous mixture of species.

2845. 35. *C. U. appendiculosum*, Lk. 91, Syn. Car. 477, and Bethlehem.

(477. 19. [Uredo] *appendiculata*. Common on *Phaseolus* and on *Pisum sativum*. (Cæomurus.))

A record in the North Carolina list that is not accounted for in the later one may be entered here, as it is the same rust, although placed by Schweinitz under *Puccinia* and erroneously referred to a name belonging to another species of rust.

(490. 5. [Puccinia] *Aviculariæ* $\beta\beta$ Fabæ. Not infrequent on *Phaseolus*.)

Represented by a mounted packet loosely containing three leaflets of the garden bean (*Phaseolus vulgaris* L.) and two leaflets of garden pea, while the original packet labelled "Cæoma (Ured) *appendiculos* Beth," has one leaflet of bean and two of pea. The bean leaflets are well covered beneath with uredinia. The pea leaflets are discolored with spots but have no rust; furthermore, no rust has ever been found in America on the garden pea, *Pisum sativum*. Schweinitz mistook the spots for a common European rust, which he naturally expected to find under the same conditions here as in Europe.

The rust on the leaflets of *Phaseolus*, the common bean, is *Uromyces appendiculatus* (Pers.) Fries. The European rust on *Pisum* is a different species. The specimen preserved doubtless represents no. 477 of the Carolina list, showing the uredinial stage of the rust, while no. 490 of the same list is unrepresented by a collection, and as it was placed under *Puccinia*, doubtless had reference to the telial stage of the same rust.

2846. 36. C. U. punctuosum, Lk. 93, Syn. Car. 474, [as U.] scutellata, also Bethlehem on *Euphorbia hypericifolia*.
(474. 16. [Uredo] scutellata. More or less frequent on *Euphorbia hypericifolia*.)

Schweinitz had an entry in his Carolina list, which is nowhere referred to in the later one. It can be entered here, as it is the same rust, although he placed it under his section "Rubigo."

- (459. 1. [Uredo] *Euphorbiæ*. Not rare on leaves of *Euphorbia maculata*.)

Represented by some four pieces of branched stem about 3 cm. long, with leaves, more or less fragmentary, inflorescence and mature seeds, showing a few, scattered uredinia, placed loose in a mounted packet, and by an original packet, containing a few similar fragments, labelled "*Cæoma* (Ured) punctuos in *Euphorb hypericif Beth.*" Another original packet containing fragments of branched stems about 2 cm. long, with leaves and inflorescence, but not mature seeds, was first labelled "*Cæoma* (Ur) *Euphorbiæ hypericif non scutellat* Sal & Bet," then the specific name was cancelled and "punctuosum" substituted. The latter packet doubtless represents the Salem collection and the former one the collection from Bethlehem. There is no material or packet for the collection on *E. maculata*.

The rust is *Uromyces proëminens* (DC.) Pass., showing varying proportions of uredinia and telia. In the interim between his two lists Schweinitz had ascertained that the European name used in his earlier list, "*U. scutellata*," applied to another rust which he had not found in America. The hosts are *Chamaesyce Preslii* (Guss.) Arth. (*Euphorbia Preslii* Guss., *E. hypericifolia* having recently been ascertained to be a more southern species) and *Chamaesyce maculata* (L.) Small (*Euphorbia maculata* L.).

2847. 37. C. U. Leguminosarum, Lk. 92, Syn. Car. 476, [as U.] *Viciæ*, on *Vicia Faba*, Bethlehem and Salem.
(476. 18. [Uredo] *Viciæ*. Fabæ. On the stems of *Vicia Faba*.)

There is no mounted specimen or original packet to represent these entries.

If a rust were really present, as there may have been, it was *Uromyces Fabæ* (Pers.) DeBary, which is occasionally found on the English bean, *V. Faba*, in America, but is more common on native species of *Vicia* and *Lathyrus*.

*2848. 38. C. U. *Lobeliæ cardinalis*, L.v.S., rather rare on the under surface of leaves of *Lobelia cardinalis*, Nazareth.

C. spots obsolete, sori effused-confluent, not elevated, or surrounded by the epidermis. Spores effused, pedicelled, chocolate-purplish.

Represented by a lanceolate, serrate leaf, about 6 cm. long, and 1.5 cm. wide, mounted, and by an empty packet labelled on the inside "*Uredo Lobeliæ cardinalis*," and on the outside "*Cæoma (Ured) Lobeliæ Cardinal* L.v.S. Beth."

The leaf is well covered with a brown effused growth due to a Hyphomycetous fungus, *Cercospora effusa* (B. & C.) E. & E.

*2849. 39. C. U. *Thalictri*, L.v.S., very rare but beautiful, on leaves of *Thalictrum cornuti*, Bethlehem.

C. spots none. Sori pulvinate, roundish—a line or more in diameter, widely aggregated, somewhat surrounded by the epidermis. Spores rather large, and from chocolate to fuscous.

Represented by part of a leaf, 1.5 by 2 cm., mounted, and by an empty packet labelled "*Cæoma (Ured) Thalictri* L.v.S. Naz."

The leaf is thickly and evenly covered with round, brown sori, bearing 2-celled, and a few 1-celled, teliospores of the characteristic form belonging to *Polythelis Thalictri* (Chev.) Arth. (*Puccinia Thalictri* Chev.), on *Thalictrum polygamum* Muhl. (*T. Cornuti* Auct.).

*2850. 40. C. U. *brunneum*, L.v.S., on leaves of an unknown plant from the collection of Mr. Collins, Philadelphia.

C. spots yellowish, on the upper surface of the leaf. Sori applanate, irregular in form, variously confluent. Spores minute, brown-fuscous, at first conglutinate.

Represented by an oblong leaflet, about 3.5 cm. long, apparently leguminous, mounted, and by an empty packet labelled "*Cæoma (Ured) brunea* in fol exot Collins."

The leaf bears reddish-brown spots on the upper surface, their

origin being obscure. The microscope shows no evidence of mycelium, and the spots are probably not due to a fungus. This conclusion has been confirmed by Dr. C. L. Shear of Washington, D. C.

*2851. 41. C. U. *Chelidonii*, L.v.S., very rare. On leaves of *Chelidonium* sent from New York.

C. spots yellowish. Sori irregular in form, clustered, confluent. Spores rather large, fuscous and black, oval, loosely scattered.

Represented by an angularly ovate leaf, incised, 3 by 5 cm., having characteristic white hairs, especially on the veins, mounted, and by an empty packet labelled inside "*Uredo Chelidonii* Halsey NYk," and outside "*Cæoma* (Ured) *Chelidonii* LvS NewYk Halsey."

The error in mistaking *Osmorrhiza* for *Chelidonium* was pointed out by Dr. W. G. Farlow in the preface to his "Host Index of Fungi," 1888.

The mounted fragment of leaf bears two small groups of brown sori on the under surface, rather pulverulent, having both urediniospores and teliospores present, identical with *Puccinia Pimpinellæ* (Str.) Mart. (*P. Osmorrhizæ* C. & P.), and essentially the same as nos. 2829 and 2841. It is a curious result of too credulously accepting the first impression of the identity of a host that led Schweinitz three times to describe the same rust from the same host, as if representing three independent species on three wholly unlike and unrelated hosts.

4. *Albugo*.

Note.—Two numbers are given under this heading, both true representatives of the accepted Phycomycetous genus *Albugo*, and they are, therefore, omitted here.

5. *Sporidiis inæqualibus* (spores unequal).

*2854. 44. C. U. *gyrosum*, Lk. 105, on leaves of *Rubus Idæus*, Bethlehem.

Represented neither by specimen nor packet. There is, however, an original packet labelled "*Cæoma* (Ur) *gyrosa* Reb. in *Rub. Id.* Kunze," and a similar one in the Herb. Curtis at Harvard University. This collection shows a few small fragments of raspberry

leaves, bearing pycnia and æcia of a *Phragmidium* on their upper surface. It is possible that this European material represents the entry, inadvertently made for North America. It seems more probable that Schweinitz found a rust at Bethlehem, which he considered the same, but for which there is now no specimen. If so, the host was probably the European red raspberry, at that time much cultivated in American gardens. In that case the rust may have been the æcial stage of *Phragmidium imitans* Arth., although Schweinitz nowhere records the more striking telial stage. The exact status of the record necessarily remains uncertain.

*2855. 45. C. U. cylindricum, Lk. 108, on *Populus italica*, Bethlehem.

Represented by a 5 cm. square portion, cut from a large, firm leaf, mounted, and by a few small fragments in the original packet, which is labelled "*Cæoma* (Ur.) *cylindrica populina* Bet."

The fragments of leaf are well besprinkled with uredinia, and the microscopic examination shows essential similarity to the uredinal stage of *Melampsora Medusæ* Thüm., the common American rust on various species of *Populus*. The host may well be the Lombardy poplar (*Populus dilatata* Ait.), as stated, although no other collection on this host has come to hand.

*2856. 46. C. U. epiteum, Lk. 112, on leaves of *Salix nigra*, over nearly the whole tree, Bethlehem.

Represented by two short stems with respectively two and three attached leaves and three unattached leaves placed loosely in a mounted packet, and by small fragments of a young stem and leaves in the original packet, which was at first labelled "*Uredo epiteum* in *Salici nigri* Beth," then the word "*epiteum*" crossed out and "*Saliceti*" substituted, and afterward the first wording restored. All the leaves are covered beneath rather sparingly with uredinia.

The collection is the first to be recorded for the very common American form on various willows, *Melampsora Bigelovii* Thüm. The spores are noticeably small and thin-walled for the species. The willow rusts are yet imperfectly understood. The host is clearly *Salix nigra* Marsh.

β . Subgenus *ÆCIDIUM*.

- *2857. 47. *C. A. Convallarium*, Lk. 114, on leaves of *Smilacina racemosa*, Bethlehem, very rare.

Represented by a mounted specimen of the middle part 4.5 cm. long, of a 2.5 cm. wide leaf, bearing beneath about ten small groups of circinating æcia, and by an empty packet labelled "*Æcid Convallarium* Salem."

The rust is an heteroecious form, without doubt, and is usually considered to be the æcial stage of *Puccinia Majanthæ* (Schum.) A. & H., occurring in both Europe and America on *Phalaris* and other grasses, but the genetic connection has not been fully established for the American material.

We must assume that "Salem" on the original packet was an error for "Bethl," in view of the printed record, which is starred and does not mention Salem.

The host was doubtless as stated, *Vagnera racemosa* (L.) Morong (*Smilacina racemosa* Desf.)

2858. 48. *C. A. Uvularium*, L.v.S., Syn. Car. 453, hardly *C. Allium* as referred by Link, n. 116, for it differs in having spots rather small, never exceeding a fourth of an inch, also in being white.

(453. 24. [*Æcidium*] *Uvulariæ* Sz.

A. orbicular, white, delicate, peridia excentric, circinate, white, spore-mass white.

Here and there on the leaves of *Uvularia perfoliata*. Peridia crowded in concentric circles, none in the center itself. Similar to *A. Allii ursini*, but the color in that is yellowish.)

Represented by the proximal half of two perfoliate leaves attached to the 2.5 cm. stem, mounted, one of the leaves bearing a single, rather diffused group of æcia, and also by an empty packet, labelled on the inside "*Æcidium circinatum* Rhlg In *Uvularia perfol* & *Polygonatum* Salem," and on the outside "*Æcidium Uvularium* LvS. Salem."

This rust has the same uncertain status as the preceding one, but is generally considered the æcial stage of *Puccinia Majanthæ* (Schum.) Arth. Schweinitz's name was changed on p. 309 of his later work to *Æcidium (Cæoma) uvularium*.

2859. 49. C. A. *Smilacinatum*, L.v.S., Syn. Car. 452, Lk. 117, not yet met with in Pennsylvania.

(452. 23. [*Æcidium*] *Smilacis* Sz.

A. wart-like, convex below, concave above, yellow-red, peridia copious, spores white.

Here and there on leaves of *Smilax rotundifolia* and *laurifolia*. Very distinct. Making thick, conic-cylindric warts on the under side of the leaf. These warts are somewhat truncate and on the pulvinate-truncate part covered with sunken peridia, two lines to a quarter of an inch wide and two or three lines high. Spores white, rather large, oval, vesicular.)

Represented by a nearly round leaf, 5 cm. in diameter, mounted, bearing one group of æcia, and by an empty packet labelled inside "*Æcidium Smilacis* In *S. rotundifol* & al Salem," with the addition "*Cæoma Smilacinatum*," and on the outside "*Æcidium Smilacinatum* LvS Salem."

This is the æcial stage of *Puccinia Smilacis* Schw., a rust that is widely distributed in the southern states, and tropical America. The æcia are rarely collected, and so far have been reported only from North and South Carolina. The name was changed by Schweinitz to *Æcidium* (*Cæoma*) *smilacinatum* on page 309 of his later work.

2860. 50. C. A. *Aroidatum*, L.v.S., Syn. Car. 457, [as A.] *Caladii*, on *Arum virginicum*, Salem.

(457. 28. [*Æcidium*] *Caladii* Sz.

A. simple, on very extended areas, peridia rufous-yellow, sphæria-form, spore-mass orange.

Frequent in some years on the midrib of the leaves and the stems of *Caladium sagittæfolium*; it kills the plants. The closed peridia resemble *Sphærias*).

Represented by the middle part, 3 cm. long, of a 5 cm. wide leaf, with over-mature æcia along midrib and large veins, now eaten by insects, and by an empty packet labelled inside "*Æcidium Caladii* In Calad. Salem," with the later addition "*Cæoma aroidatum*," and on the outside "*Æcidium Caladiatum* LvS. Salem," with the subsequent addition "*Aroidat*."

This is the æcial stage of *Uromyces Caladii* (Schw.) Farl., and on *Peltandra virginica* (L.) Kunth (*Arum virginicum* L.), see also no. 2839. The name *Cæoma Aroidatum* should have been credited

to Link, n. 118. Schweinitz changed the name to *Æcidium* (*Cæoma*) *aroidatum* on page 309 of his later work.

- *2861. 51. *C. A. Dracontionatum*, L.v.S., frequent on leaves and petioles, and also on the scapes of *Arum dracontium*, Bethlehem. Not the same as the preceding. Also Salem.
C. spots pale, widely scattered over the leaf, occupying nearly the whole of it. Pseudoperidia large, scattered irregularly in dense clusters on the spot. Spores orange color.

Represented by a much broken leaf, 3 by 5 cm., mounted, thickly covered beneath with large æcia, and by a packet labelled inside "*Æcidium Dracontii* In Aro Dracont Salem," and on the outside "*Æcidium Dracontiatum* LvS Salem," containing a few very small fragments of leaf, showing æcia.

The differences noted by Schweinitz between this collection and the preceding one are now ascribed to the influence of the host, and the form is referred to *Uromyces Caladii* (Schw.) Farl, the host being *Muricauda Dracontium* (L.) Small (*Arum Dracontium* L., *Arisæma Dracontium* Schott.). The name of the rust was changed to *Æcidium* (*Cæoma*) *dracontionatum* on page 309 of his later work.

- *2862. 52. *C. A. rubellatum*, Lk. n. 120, rather rare on various species of *Rumex*, Salem and Bethlehem. Spots generally sterile.

It is evident that Schweinitz should have cited here the following similar entry in his North Carolina list, and have omitted the asterisk.

- (433. 4. [*Æcidium*] *Rumicis*. Frequently seen as spots on *Rumex* and *Grossularia*; but the fungus is very rarely perfect.)

No specimen or packet remains to represent these records nor is there any in the Herb. Curtis at Harvard University. Both entries are without doubt founded upon errors of observation. *Rumex* leaves are often spotted from the action of fungi imperfecti which could easily be mistaken for the small æcia not uncommon on this host in Europe. The mention of *Grossularia* was doubtless in conformity with Persoon, who thus associates these hosts.

2863. 53. *C. A. Lysimachiatum*, Lk. 126, Syn. Car. 438, absolutely the same. In Pennsylvania, generally on *L. racemosa*.

(438. 9. [*Æcidium*] *Lysimachia* Sz.

A. diffuse, pale, rather small, epiphyllous, peridia crowded, dentate, spore-mass somewhat flesh colored.

On leaves of *Lysimachia quadrifolia* and *stricta*, unless perchance two species exist; for the one on *quadrifolia* is not pale, but tinged with a red color. It makes a rather small spot on the upper surface of the leaves.)

Represented by a somewhat torn leaf, 1.5 by 4 cm., bearing beneath a rather diffuse, compound group of old æcia, and by an empty packet labelled inside "*Æcidium Lysimachia* in *L. quadrifol* Sal," and on the outside "*Æcidium Lysimachiatum* in *L. quadrif. Salem*."

Schweinitz's statement, "absolutely the same," doubtless refers to a note in Link's work as to the identity of American and European material, which mycologists still hold in general with Schweinitz to be one, although Link was too uncertain about the matter to accept Schweinitz's name as a basis or even as a synonym of his *C. Lysimachiatum*, founded upon Schlechtendahl's *C. Lysimachia*, which was published two years later than Schweinitz's name. The fungus is now accounted the æcial stage of the *Carex* rust, usually called *Puccinia limosæ* Magn., a widely scattered but rather local species, recently given the name *P. lysimachiata* (Link) Kern, there being already a *P. Lysimachia* of Karsten, 1879.

Both spot and æcia on the mounted leaf still appear reddish, as stated by Schweinitz for *L. quadrifolia*. The two names, *L. stricta* Ait. and *L. racemosa* Lam., are now considered synonyms of *L. terrestris* (L.) B. S. P.

2864. 54. *C. A. Pentstemoniatum*, L.v.S., Syn. Car. 449, Lk. p. 47, only observed in Carolina.

(449. 20. [*Æcidium*] *Pentstemonis* Sz.

A. orbicular, rather small, dense, purple, yellow beneath, peridia white, congested.

Not infrequent on leaves and stems of *Pentstemon hirsutus*. Distinct species. Two lines broad. Peridia large for the size of the plants. Spores yellow-brown, simple, vericulose.)

Represented by an original packet, containing three fragmentary

leaves and a small portion of a stem, now in rather poor condition, and showing only a few æcia on one of the leaves, labelled inside "*Æcidium Pentstemonitis* Salem," and on the outside "*Æcidium Pentstemoniat* LvS. Salem." Although there is no mounted specimen there are pin marks where one may have been attached.

The rust is common in the eastern United States, and is the æcial stage of no. 2911, *Puccinia Andropogonis* Schw., as proven by cultures first made by the senior author in 1899 (*Bot. Gaz.*, 29:272), and subsequently repeated a number of times. The southern *Pentstemon*, corresponding to the northern *P. hirsutus*, is *P. australis* Small. Schweinitz changed the name of the rust to *Æcidium* (*Cæoma*) *pentstemoniatum* on page 309 of his later work.

2865. 55. C. A. Apocynatum, L.v.S., Syn. Car. 448, Lk. n. 135, not yet [seen] in Pennsylvania.

(448. 19. [*Æcidium*] Apocyni Sz.

A. orbicular, very large, orange, pale below. Peridia arranged in a few concentric circles, somewhat fuscous.

On leaves of *Apocynum cannabinum* in the mountains. Spots delicate. Peridia when closed from yellow to chestnut-brown or somewhat fuscous, when open with a pale, lacerate margin. Spores simple, white.)

Represented by a mounted specimen of the middle part, 4 cm. long, of a 3.5 cm. wide leaf, bearing beneath two groups of æcia, centrally placed on dark spots 7 mm. across, and by a packet containing a small part of a leaf, showing no fungus. and labelled "*Æcidium Apocyniatum* in Apocyn. pubes. Salem."

This rust is not much better understood than in the days of Schweinitz. Only six other collections are known to the writers, which have come from Delaware, New Jersey, District of Columbia and North Carolina. It is probably a heteroecious form, but no suggestion has been made regarding the alternate host. The name was written *Æcidium* (*Cæoma*) *apocynatum* by Schweinitz on page 309 of his later work.

2866. 56. C. A. Convolvulatum, L.v.S., Syn. Car. 454, very frequent also in Pennsylvania on *C. panduratus*.

(454. 25. [*Æcidium*] *Ipomœæ-panduranæ* Sz.

A. very large, bullate, depressed above, white, peridia flexuose, rather large, elevated, ruptured by a slit, spore-mass cinereous-golden-red.

Frequent on the leaves of *Ipomœa* (Convolv.) *pandurana*. Peridia thick, the loose epidermis larger than in almost any *Æcidia*, except *cornutum* and *cancellatum*. Spores rather small, oblong.)

Represented by a mounted stem, 7 cm. long, and part of two leaves, and by an original packet, containing ample material, and labelled inside "*Æcidium Ipomœæ in pandurata & lacunosa* Salem," and on the outside "*Æcidium Convolvuliat* LvS. Salem & Beth in Conv. *pandurat*."

The fungus is certainly and wholly *Albugo Ipomœæ-panduranæ* (Schw.) Swingle one of the Peronosporales, and not a rust. The name was changed to *Æcidium (Cæoma) convolvulatum* at page 309 of the later work.

2867. 57. C. A. Compositarum, Lk. n. 139, and frequent in Pennsylvania.

α *Prenanthis* on *Krigia*, Salem, Syn. Car. 434.

β *Eupatoriæ*, Bethlehem, frequent on *E. purpureum*.

(434. 5. [*Æcidium*] *Dandelionis* Sz.

Why not merely a variety of *Æcidium prenantis*, to which it is very similar? Spores subglobose, without septum and pedicel, chestnut-brown. On leaves and stems of *Tragopogon Dandelion*. Rare.)

Represented by an original packet, containing a few very small fragments of a leaf with many æcia, and labelled inside "*Æcidium Eupatoriæ maculatæ* Bethl," and on the outside "*Æcidium Eupatoriatum* LvS Beth," with "*compositatum*" written above. There is no packet for the other entry, and no mounted material for either, although there is indication that there may once have been a mount where pin marks now show.

The æcia on *Eupatorium* are doubtless to be assigned to the widespread rust, *Puccinia Eleocharidis* Arth., very common both north and south, the uredinia and telia being on various species of *Eleocharis*, and the æcia on various species of *Eupatorium*, including both *E. maculatum* L. and *E. purpureum* L. As the fragment in the original packet shows the leaf to be smooth above with minute sparse pubescence beneath and not at all scabrous, the host is doubtless *E. purpureum* and not *E. maculatum*, the conclusion evidently reached by Schweinitz.

The identity of the form on *Krigia* is somewhat uncertain. The

color of the spores fits well the uredinia of *Puccinia Pyrrhopappi* Syd. (*P. Krigiae* Syd.), the only known collection on *Krigia* having been made by Dr. B. L. Robinson at Asheville, N. C., Aug. 2, 1893, on *K. virginica* Willd. But that form of rust has scattered sori, and not clustered as in an *Æcidium*. Schweinitz thought the fungus not unlike *Æcidium Prenanthis* Pers., and fortunately there is a specimen of this species in the Schweinitz collection, which had been received from Kunze. It consists of a smooth, thin, deltoid leaf, some 5 or 6 cm. across, which bore a single cluster of æcia, most of which has now disappeared. It is clear, nevertheless, that Schweinitz must have had an æcidioid fungus on the *Krigia*. The only known form on *Krigia* with clustered sori having "chestnut-brown" spores is that of the short-cycle species which at another time and on another host Schweinitz called *Puccinia maculosa* (see no. 2922). The teliospores germinate at maturity in the sorus, and placing some of them under such magnification as Schweinitz probably used, gives the appearance of "spores subglobose, without septum and pedicel."

The host was well known to the contemporaries of Schweinitz, and commonly called the "small dandelion" (see Muhlenberg's Catalogue, p. 71). It was considered closely related to *Prenanthes*. The latest form of the name is *Adopogon Dandelion* (L.) Kuntze.

*2868. 58. C. A. Hieraciatum, L.v.S., here and there on the leaves of *H. paniculatum* and *maculatum*, Bethlehem.

C. spots deep purple, widely effused. Pseudoperidia circinate, on the center of the spot, margins beautifully fimbriate, spores orange.

Represented by 5.5 cm. of a lanceolate leaf, 2 cm. wide, denticulate, slightly pubescent beneath, having two groups of æcia, and by an empty packet labelled "*Æcidium hieraciatum* Lv Hieracii paniculatum Beth."

The host is correctly named, for the leaf exactly matches the leaves of a phanerogamic specimen collected by Schweinitz at Salem, N. C., now in the herbarium of the Philadelphia Academy, which is without question *H. paniculatum*.

The name of the rust was changed by Schweinitz to *Æcidium* (*Cæoma*) *hieraciatum* on page 309 of the same work. The rust is

undoubtedly identical with a widespread species, having telia on *Carex* and æcia on many Cichoriaceous hosts, but it has not been reported by any other collector on *Hieracium paniculatum*. The species has generally been called *Puccinia patruelis* Arth., but Schweinitz's specific name is much older and should therefore be used, making the name **P. hieraciata** (Schw.) comb. nov. No other collections of *P. hieraciata*, either of æcial or telial stages, are known with certainty east of Michigan and Indiana, but it is not improbable that the species occurs sparingly in the eastern mountains.

*2869. 59. C. A. *Erigeronatum*, L.v.S., rather rare but ample on *E. heterophyllus*, Bethlehem.

C. spots very large, yellowish, rather thick. Pseudoperidia densely and irregularly scattered, elevated. Spores yellowish.

Represented by the major part, 5.5 cm. in length, of two leaves, 2 and 3 cm. broad respectively, the smaller showing four groups of æcia, and the larger many æcia thickly and evenly grouped over an area 2.5 cm. across, and also by an empty packet labelled inside "*Æcidium Flosculosorum* Salem," later added below "in *Solidago*, *Erigeron*, *Aster*," and still later added above "*Cæoma asteratum*," and finally "*erigeronatum*," and also labelled on the outside "*Æcidium compositat Erigeronatum* Lvs Bethl."

The host, which has been compared with phanerogamic specimens, is certainly *Erigeron annuus* Pers. (*E. heterophyllus* Muhl.), and the rust is the common one on this host, being the æcial stage of *Puccinia Asterum* (Schw.) Kern. and belonging to the physiological race represented by the name *Puccinia Caricis-Erigerontis* Arth., as proven by cultures. Schweinitz changed his name to *Æcidium (Cæoma) erigeronatum* on page 309 of the same work.

2870. 60. C. A. *Asteratum*, L.v.S., Syn. Car. 444, Lk. 143, common, especially on *A. paniculatus*. Link does well to join with this *C. Solidaginis*, Syn. Car. 446, and *C. Verbesinæ*, 445. But *C. Helianthi* does not belong here.

(444. 15. [*Æcidium*] *Asterum* Sz.

A. effuse, confluent, very delicate, pale, purplish, peridia aggregated, immersed, spore-mass white.

Here and there on leaves and stems of smooth leaved *Asters*.—Spores rather large, vesicular, globose or oblong, simple.)

(445. 16. [*Æcidium*] *Verbesinæ* Sz.

A. oval, rather thick, small, pale reddish yellow, peridia few, prominent, white.

Frequent on *Verbesina*, *Sigesbeckia*, and others. Spots four lines in diameter. Spores simple, very small, pale, margins of the peridia entire.)

(446. 17. [*Æcidium*] *Solidaginis* Sz.

A. effuse, rather large, peridia scattered, minute.

Frequent on stems of *Solidagos* before flowering. Similar to the preceding.)

Neither specimens nor packets remain to represent these entries. Schweinitz was right in putting the *Solidago* æcia with those on *Aster*. They go with the *Aster-Solidago-Erigeron-Carex* combination lately passing under the name, *Puccinia extensicola* Plowr., along with the preceding number, one belonging to the physiological race, *Puccinia Caricis-Asteris*, and the other to that of *P. Caricis-Solidaginis* as abundantly indicated by cultures. The present accepted name is *Puccinia Asterum* (Schw.) Kern.

He was also right in excluding *A. Helianthi-mollis*, here given under the subsequent number; but he was wrong in retaining *A. Verbesinæ*. The *Verbesina* æcia belong with the autoëcious rust *Puccinia Verbesinæ* Schw. (see no. 2925), a rust which is common throughout the southern states. All collections of this species appear to be on *V. occidentalis* (L.) Walt., which doubtless was the host of Schweinitz's no. 445. No rust has yet come to hand on *Siegesbeckia* (*Actinomeris*), and the inclusion of the name must have been due to an assumption not supported by collections. Schweinitz claimed authorship of this species, hence places his initials after the name, although Link was the first to write it in this form, as Schweinitz was well aware. The name was written by Schweinitz *Æcidium* (*Cœoma*) *asteratum* on page 309 of his later work.

2871. 61. *C. A. Helianthatum*, L.v.S., Syn. Car. 450, frequent on *H. mollis*.
Rare in Pennsylvania.

(450. 21. [*Æcidium*] *Helianthi mollis* Sz.

A. oblong, thick, whitish, peridia congested, pale, spores oblong.

Frequent on the under side of the leaves of *Helianthus mollis*;

hairy. Spores under the microscope yellow-fuscos, vesicular; when old pellucid, white.)

Represented by a lanceolate, very tomentose leaf, 4.5 cm. long, and part of another similar leaf, both mounted, showing small groups of æcia. An empty packet is labelled inside "*Æcidium Helianthi mollis* Salem," and outside "*Æcidium helianthatum* LvS. on *Helianthi molli* Salem."

The name was changed by Schweinitz to *Æcidium* (*Cæoma*) *helianthatum* on page 309 of his later work. This collection represents the basis for the earliest name to be applied to any part of the cycle of the American sunflower rust which is generally called *Puccinia Helianthi* Schw. A less convenient, but technically more correct name, therefore, is **P. Helianthi-mollis** (Schw.) comb. nov.

*2872. 62. C. A. *Trachelifolium*, L.v.S., here and there on the leaves of *Helianthus trachelifolius*, Bethlehem.

C. spots broadly effuse, yellowish or rufous, confluent, large. Pseudoperidia very densely aggregated in the center, as if crowded and appressed to each other, and hence somewhat angular, moderately elevated; margin not fimbriate. Spores yellow, finally decolored.

Represented by parts of two originally large leaves, 3 and 4 cm. broad respectively, mounted, and by three broken leaves and many fragments in the original packet, which is labeled "*Æcidium Helianthi trachelif.*" The leaves bear a number of groups of æcia.

The fungus is the æcial stage of the common sunflower rust, *Puccinia Helianthi-mollis*, and the host, so far as the specimen shows, is as given by Schweinitz. The name was changed by Schweinitz to *Æcidium* (*Cæoma*) *trachelifolium* on page 309 of the same work.

*2873. 63. C. A. *Gnaphalium*, L.v.S., striking and very common in the late autumn on leaves (under side), also on the woolly stems of *Gnaphalium polycephalum*, Bethlehem.

C. hypophyllous, at first cloaked in the wool of the leaves and stems. Spots more or less effuse, yellowish. Pseudoperidia only a few, but densely approximate, very often even single, very long, and very white, cylindric, apex fimbriate. Spores orange yellow. It is related to C. *Pini* in the form of the peridium.

Represented by two stems, each 6 cm. long, and many crumpled

leaves, loose in a mounted packet, and by two original packets, one containing a stem 12 cm. long, and a few leaves, labelled "*Æcidium Gnaphalites* LvS 1828," and another containing a few leaves labelled "*Cæoma Æcidium Gnaphalitum* LvS. spec. exim." The collection shows a few æcia.

The host is without doubt *G. obtusifolium* L. (*G. polycephalum* Michx.), and the rust is the æcial form of what has commonly been called *Puccinia investita* Schw. (no. 2932), but owing to the priority in position of the present specific name, should be called **P. gnaphaliata** (Schw.) comb. nov. The name was changed by Schweinitz to *Æcidium (Cæoma) gnaphalitatum* on page 309 of the same work.

2874. 64. C. A. Clematitatum, L.v.S., Syn. Car. 447—and collected in Pennsylvania—a good species.

(447. 18. [*Æcidium*] Clematidis Sz.

A. pale red, peridia congested, few.

On younger leaves of *Clematis Virginiana*, Bethany. A valid species?)

Represented neither by a specimen nor a packet. In his Carolina list Schweinitz was in doubt about the validity of his species, but later felt assured, and consequently added "a good species" in his later list. There can be no question, however, that the fungus is one identical with the well-known *Æcidium Clematidis* DC., and which has now been proven by cultures in both Europe and America to be the æcial stage of *Puccinia Clematidis* (DC.) Lagerh. (*P. Agropyri* Ellis & Ev.).

The variable use of *t* and *d* in forming the suffix was not uncommon among the earlier mycologists, where in recent years *d* only is employed, thus the spelling "Clematidis," instead of *Clematidis*, etc.

Schweinitz changed the name to *Æcidium (Cæoma) clematitatum* on page 309 of his later work.

2875. 65. C. A. Ranunculaceatum, Lk. [n.] 150. Frequent, Carolina (Syn. Car. 440) and Pennsylvania on various species of *Ranunculus*, e. g. *R. abortivus* and others.

- (440. II. [*Æcidium*] *Ranunculi* (abortivi). Frequent on the round radical leaves, almost devoid of spots.)

Represented by three radical leaves of *Ranunculus abortivus* L., 2.5 cm. broad, mounted, well covered beneath with æcia, and by an empty packet labelled inside "*Æcidium Ranunculi nitidi* Salem," and outside *Æcidium ranunculi*at *Ran abortivi* Sal & Bet."

Schweinitz was correct in his first list in considering this fungus distinctive, and in error later in assigning it to Link's inclusive species. It occurs only in America, and in the eastern United States only on *Ranunculus abortivus*, being the æcial form of *Puccinia Eatoniae* Arth.

- *2876. 66. C. A. *Cimicifugatum*, L.v.S., very beautiful, rather rare on leaves of *Cimicifuga racemosa*, Bethlehem. Where found almost all leaves are infested.

C. spots large, orbicular, yellow, bullate. Pseudoperidia on the lower surface, concentric, very long, cylindric, apex at first closed, then subfimbriate. Spores orange, becoming white.

Represented by parts of three leaves, each part about 4 cm. long, mounted, showing considerable groups of very long cylindric peridia, and by an empty packet labelled inside "*Æcidium Actææ* near Easton on Delaware very rare," and on the outside "*Æcidium Actææ*atum LvS Bethl," with *Actææ*atum crossed out and "*Cimicifugatum*" substituted for it.

This imperfectly known rust is even at the present time a rare form. It is probably heterœcious, and may belong to some grass rust. Schweinitz changed the name to *Æcidium (Cæoma) cimicifugatum* on page 309 of the same work.

- *2877. 67. C. A. *Hibisciatum*, L.v.S., on leaves of *Hibiscus militaris*, Bethlehem, cultivated, not rare.

C. spots orbicular, yellowish, confluent. Pseudoperidia irregularly but densely scattered, delicate, yellow. Spores not compact but loose, yellowish.

Represented by one obliquely triangular-ovate leaf, 3 by 5 cm., mounted, having many groups of æcia, and by an empty packet labelled "*Cæoma Æcidium Hibiscatum* LvS in *H. militaris* Beth."

The rust is the æcial stage of *Puccinia hibisciata* (Schw.)

Kellerm. (*P. Muhlenbergiae* Arth. & Holw.), on *Muhlenbergia* and other grasses, as repeatedly proven by cultures. Schweinitz changed the name to *Æcidium* (*Cæoma*) *hibisciatum* on page 309 of the same work.

- *2878. 68. C. A. *Hepaticatum*, L.v.S., scarcely *C. quadrifidum*, Lk. n. 152. Here and there on degenerate leaves, i. e., not trilobate, but nearly reniform and multilobed, of *Anemone hepatica*, Bethlehem.
C. spots entirely wanting; the leaf, nevertheless, on which it rests degenerates. Pseudoperidia very large, broad, the margin exactly cleft into four parts, revolute, the lobes broad, brown. Spores fuscous-brown. Occupying the whole leaf.

Represented only by an empty packet labelled "*Æcidium Hepaticatum* Bethlehem, 24."

It is probable that the failure to recognize this rust as the *Æcidium quadrifidum* DC., found on *Anemone* in Europe, was largely due to the peculiar distortion of the leaf produced by the fungus in the case of *Hepatica*. The form on both *Hepatica* and *Anemone* is the æcial stage of the plum rust, *Tranzschelia punctata* (Pers.) Arth. (*Puccinia Pruni-spinosæ* Pers.), and is on the common liverleaf of the eastern states, *Hepatica Hepatica* (L.) Karst. (*H. triloba* Chaix., *Anemone Hepatica* L.). The combination *Æcidium* (*Cæoma*) *hepaticatum* is made by Schweinitz on page 309 of the same work.

2879. 69. C. A. *Geraniatum*, Lk. 156, on leaves of *Geranium maculatum* and *G. carolinianum*. Exactly identical with the European. Syn. Car. 443.

(443. 14. [*Æcidium*] *Geranii maculati* Sz.

A. diffuse, hypophyllous, thickened, red, peridia dense, broad, smooth on the margin, spores yellow.

Frequent and large on leaves of *Geranium maculatum*. On the upper surface of the leaves it makes a diffuse spot. Peridia densely aggregated. Spores simple, globose, cellular under the microscope, yellow-fuscous; some are united in pairs as if compound, and very rarely are furnished with a pedicel.)

Represented by the central part of a leaf, 2 by 3 cm., mounted, showing one large group of æcia, and by an empty packet labelled inside "*Æcidium Geranii maculat* Salem," and on the outside "*Æcidium Geraniatum* LvS *G. maculat* Salem."

Schweinitz's inclusion of *Geranium carolinianum* as one of the hosts must have been a hasty generalization. A specimen of this plant in the phanerogamic herbarium at the Philadelphia Academy of Sciences, obtained by Schweinitz at Salem, shows that he was familiar with the plant, but no æcia are known to have ever been collected on the species, or on any American *Geranium* with similar leaves.

Although Schweinitz adopted Link's name, yet Link hesitated to place the American rust under his species, and properly so as time has proven. Link's form is a stage of *Uromyces Geranii* (DC.) Oth & Wartm., an entirely different rust.

The Schweinitz form is the æcial stage of *Puccinia Polygoni-amphibii* Pers., as established by cultures in both this country and Europe. Recently some European mycologists have considered that the American form of this widespread species should be treated as distinct from the European form. But it would doubtless be better to consider the species as made up of a number of more or less distinct races, and that the common form in America is a race different from the common form in Europe.

2880. 70. C. A. Impatientatum, L.v.S., Syn. Car. 442, Link pag. 57 in a note, also Bethlehem.

(442. 13. [Æcidium] Impatientis Sz.

A. effuse, large, becoming pale, peridia in the center, sparse, crenate, spores rather large, yellow-fuscos, simple.

Frequent in May on the leaves of *Impatiens maculata*. It swells the leaves and stains a broad yellowish spot, darker in the center.)

Represented by part of a leaf, about 3 cm. long, and 2 cm. wide, mounted, bearing a single large group of æcia, and by an empty packet labelled inside "Æcidium Impatientis Salem," and outside "Æcidium Impatientat LvS Salem."

Link, at the place cited, indicated the possibility that this form might belong with the preceding one. It is, however, different, although having much similarity in gross appearance. It is, in fact, the æcial form of the American *Puccinia Impatientis* (Schw.) Arth. (*P. perminuta* Arth.), having telia on *Elymus*, *Agrostis* and other grasses, as proven by cultures. The name was changed by Schweinitz to *Æcidium (Cæoma) impatientatum* on page 309 of his later work.

2881. 71. C. A. Berberidatum, Lk. 157, on Berberis canadensis, Carolina.

This number is not starred, and it is probable that a reference to the record in the North Carolina list was omitted unintentionally. It is here added.

(437. 8. [*Æcidium*] Berberidis. Rather rare on leaves of Berberis vulgaris, covering the mountains of Wilkes County.)

Represented by a mounted specimen of a stout, ash-gray stem, 3.5 cm. long, having two fascicles of leaves, two full-grown leaves in one fascicle and three in the other, each leaf 1.5 by 3 cm. or somewhat less, bearing a number of small groups of young æcia, one group only appearing mature (see cut). There is also an empty

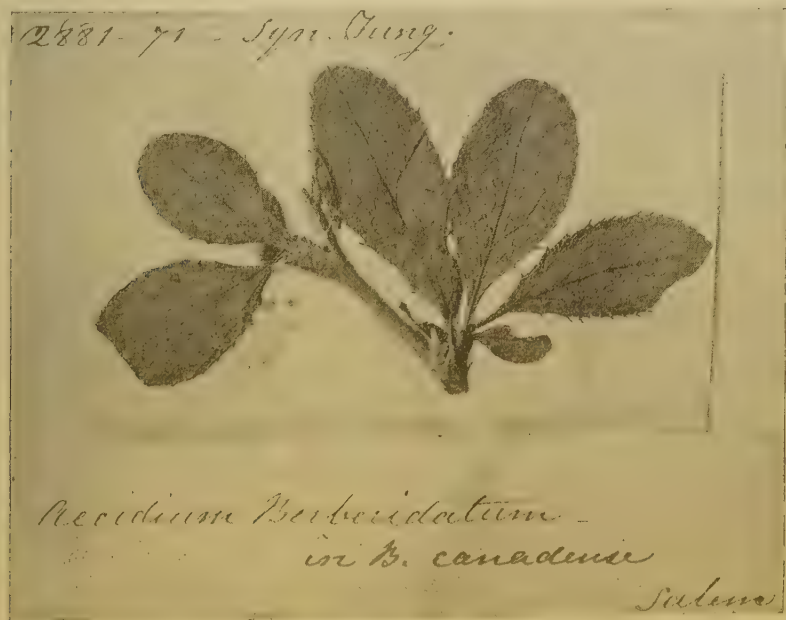


FIG. 1. From a photograph of the mounted specimen in the Academy of Natural Sciences of Philadelphia, basis of Schweinitz's No. 2881. Each specimen in the mounted set is treated essentially in the same manner. The writing was done by Michener. Engraved full size.

packet labelled inside "*Æcidium Berberidis*," and on the outside "*Æcidium Berberidat* in Berb canad Salem."

The rust is the æcial stage of *Puccinia poculiformis* (Jacq.)

Wettst. (*P. graminis* Pers.), whose telia are very common on grains and other grasses. The æcia have never been taken in America upon wild species of barberry, unless this record by Schweinitz is such an instance. In the Carolina list they are said to occur on *Berberis vulgaris* "covering the mountains of Wilkes County." Evidently Schweinitz sometime after collecting his specimen somewhere in the vicinity of Salem learned that the native *Berberis* in the mountains near Salem, N. C., is *B. canadensis*, and his collection was later so labelled and so recorded in his North American list.

There is in the herbarium of the Academy of Natural Sciences of Philadelphia an ample and characteristic phanerogamic specimen of *B. canadensis* from Salem, N. C., collected by Schweinitz, and another from Statesville, N. C., collected by Gray, Sargent, Redfield and Canby, making it certain that *B. canadensis* did occur as stated. But comparing the mounted cryptogamic specimen, which must certainly have been the original collection, it is easy to see that it does not agree well with the phanerogamic specimen by Schweinitz or the same species by others, as it has the ash-gray bark of *B. vulgaris*, instead of the dark reddish-brown bark of *B. canadensis*.

The evidence goes to show that although Schweinitz may have observed the native barberry "covering the mountains," yet the rust was "rather rare," and on *Berberis vulgaris*, as it has generally been found to occur during the years that have followed, not only in the Carolinas but throughout the eastern United States. There is no reason to think that the rust will not as readily infect any *Berberis* in its native state as it does the cultivated species, but up to the present time there is no such authentic record.

*2882. 72. *C. A. grossulariatum*, Lk. 162. Very frequent on various species of *Grossularia* in the mountains of Pennsylvania.

Represented by twenty leaves mounted loose in a packet, the largest about 2 cm. across, showing a number of small groups of æcia, and by an empty packet labelled on the outside "*Æcidium grossulariat* Mauchunk in Gros oxya," with an evident emendation written within "et Mauch Chunk Pensylva. in Rib oxyacanth Lv."

Except one greenish fragment, the leaves are all of a dark brownish tint and similar in appearance. They may well be *Grossularia oxyacanthoides* (L.) Mill. (*Ribes oxyacanthoides* L.).

The rust is the æcial stage of *Puccinia Grossulariæ* (Schum.) Lagerh., having telia on many species of *Carex*.

2883. 73. C. A. *Hypericatum*, L.v.S., Syn. Car. 451, Lk. 159, here and there, also near Philadelphia.

(451. 22. [*Æcidium*] *Hyperici frondosi* Sz.

A. suborbicular (orange), peridia cylindric, elevated (white when dry), spores white.

Frequent on leaves of *Hypericum frondosum*. Narrows of Yadkin, very beautiful, bright orange, making rather small but numerous spots sometimes almost devoid of the distinctive color. Peridia elevated as in *Æc. Rhamni*, to which somewhat related. Spores oblong, white, rather pellucid.)

Represented by a dozen or so leaves, partly attached to short stems, mounted loose in a packet, the leaves showing a few small, circular groups of white, cylindric æcia, and by an original packet containing a few leaves labelled inside "*Æcidium Hyperici frondosi* Narrows of Yadkin," and outside "*Æcidium Hypericatum* LvS Hyp frond Narrows of Yadkin Carol."

The host agrees with a phanerogamic specimen, labelled by Schweinitz "*Hypericum frondosum*, Salem," now in the collection of the Philadelphia Academy, which is identified as *H. prolificum* L. The rust is the æcial stage of *Uromyces Hyperici-frondosi* (Schw.) Arth., and is undoubtedly on *Hypericum prolificum* L. (*H. frondosum* Michx.). The combination *Æcidium (Cecoma) hypericatum* Schw. was made on page 309 of the later work.

2884. 74. C. A. *Violatum*, Lk. 158, Syn. Car. 439, on leaves of various violets of Carolina and Pennsylvania, e. g., *V. cucullata*, *obliqua*, *hastata*, and the like.

(439. 10. [*Æcidium*] *Violæ* Conspect. fung. Niesk. p. 118. Occurs especially on *Viola hastata*, but also on other stemmed violets.)

Represented by two specimens mounted, one of them being the end of a stem with two folded, cordate leaves and one young seed capsule, having æcia on the blade, petioles, stipules, and stem, and by a corresponding empty packet labelled "*Æcidium Violatum* V. *hastatæ* LvS Salem."

This specimen has large æcia, and spores that correspond to the æciospores of *Puccinia Viola* (Schum.) DC.

The other mounted specimen consists of one reniform leaf, 3 cm. broad, bearing three groups of æcia; and there is a corresponding empty packet labelled "*Æcidium Violatum* V. *obliqua* Beth."

This specimen shows smaller æcia, and much smaller æciospores than the other, and is doubtless the æcial stage of *Uromyces pedatatus* (Schw.) Sheldon. The host is in all probability *Viola primulaefolia* L.

*2885. 75. C. A. *pedatum*, L.v.S., in some years very common on leaves and petioles of *Viola pedata*, Bethlehem.

C. spots very small, much elevated and proportionally thick, purplish, almost everywhere covered with rather large, somewhat high, subcylindric pseudoperidia. Spores pale.

Represented by six leaves and one flower, mounted loose in a packet, showing many æcia, and an original packet, containing two very small leaves bearing a few small, irregular groups of æcia, which is labelled "*Æcid Viol. pedatæ* Lv Bethl."

The æcia and spores of this specimen, which are clearly on *Viola pedata* L., agree with those which were shown by cultures in 1910 to be the æcial stage of *Uromyces pedatatus* (Schw.) Sheldon (*U. Andropogonis* Tracy), having telia on species of *Andropogon*. The name was changed to *Æcidium (Cæoma) pedatatum* on page 309 of the same work.

*2886. 76. C. A. *sagittatum*, L.v.S., on leaves of *Viola sagittata*, Bethlehem. Scarcely the same.

C. spots purple, but yellowish on the lower surface. Pseudoperidia slightly elevated, sparse, without order, on bullate spots, pale. Spores concolorous.

Represented by a short caudex with five attached leaf stalks and three leaf blades, two of full size, 3 cm. long, one blade and one petiole bearing indefinite groups of æcia, and by an empty packet labelled "*Æcid. Viola sagittat* LvS Bethl."

The necessity of discriminating microscopic fungi chiefly by their gross appearance and the effect produced upon the host led Schwe-

nitz to think this collection "scarcely the same" as the preceding one on *Viola pedata*, although a careful microscopic examination shows that it has the same small spores and other characters which go with the æcia of *Uromyces pedatatus* (Schw.) Sheldon. The name was changed to *Æcidium* (*Cæoma*) *sagittatum* on page 309 of the same work.

2887. 77. *C. A. luminatum*, L.v.S., Syn. Car. [as *A.*] *nitens*, 458, also frequent in Pennsylvania on *Rubus*. The leaves, which with the whole plant are infested by this *Æcidium*, are degenerate (year after year.)

(458. 29. [*Æcidium*] *nitens* Sz.

A. simple, elongate, peridia very large, yellow, brilliant, at length irregularly ruptured, spore mass orange.

Frequent on leaves, petioles and younger shoots of *Rubus strigosus*. Its perennial return so infests plants of the whole region that finally it entirely destroys them; summer. Resembles a *Uredo*, but it has a distinct peridium. Peridia finally confluent with each other.)

Represented by five parts of leaves, each about 4 or 5 cm. long, in a mounted packet, and by many leaves and leaflets in the original packet, which is labelled inside "*Æcidium nitens* in *Rubo villosus* Salem Bethl Neujork," and in another place "*Cæoma luminatum*," and on the outside "*Æcidium luminatum* LvS in *Rub. villos* Bethl & Salem." All the leaves are covered with the rust and show the characteristic degeneration of the host.

It was the custom generally followed by Schweinitz to preserve but the one original collection to represent each species. It is quite evident from its appearance that the ample material of the present species was all gathered at one time, and that it is all, or nearly all, from one plant, as it is very uniform. A part of the material has been seen by Dr. P. A. Rydberg, who monographed the genus *Rubus* for the "North American Flora," and he states that the host can not possibly be *R. strigosus*, but that it may be *R. procumbens* Muhl., or more likely its southern representative *R. Enslenii* Walt., both of which usually passed under the name of "*R. villosus*," a century ago. It will be noticed that Schweinitz labelled his collection *R. villosus* and did not change it afterward, although he added Bethlehem and New York for additional localities, and even changed the name of the rust to what he doubtless considered a better name, and

then turned the packet and placed on the outside his final record, still with the host as *R. villosus*. It is impossible even to surmise why he used *R. strigosus* in the last printed account. The rust has never been found on *R. strigosus* in all the intervening years, and the use of that name by Schweinitz may certainly be taken as an error.

The rust itself is of special interest. Until very recently it has been identified with a similar rust of Europe, *Gymnoconia interstitialis* (Schl.) Lagerh., a long cycle, autœcious form, as proven by cultures. The same long-cycle form also occurs in this country, as also proven by cultures. Recently investigations by Kunkel have shown that there also occurs in this country a short-cycle form, whose telia are indistinguishable in appearance from the æcia of the long-cycle form, but differ in their mode of germination, and that only the short-cycle form has so far been observed in the southern states, although both forms occur northward. The senior author has recently (*Bot. Gaz.* 63:504. 1917) erected a new short-cycle genus with Schweinitz's Salem collection as the type, so that it becomes *Kunkelia nitens* (Schw.) Arth. The combination *Æcidium* (*Cœoma*) *luminatum* was made on page 309 of Schweinitz's later work.

2888. 78. C. A. Podophyllatum L.v.S., Syn. Car. 435. Link on account of my inaccurate words in Syn. Car.—“Spores bilocular,” inserted by a slip of the pen from the description of *Puccinia Podophylli*, an entirely different fungus—has wrongly placed this *Æcidium*, the most remarkable of all, among the Puccinias. Ours usually occurs with thick bullate spots, rendering the broad leaves of Podophyllum contorted and deformed—with a diameter of 4-6 inches. Pseudoperidia located in the center, slightly elevated, very densely crowded, rather large, and innumerable. The margin of the spot, however, always sterile. Spores are not bilocular. (435. 6. [*Æcidium*] *Podophylli* Sz.

A. very large, orbicular, at length diffuse, golden yellow, very dense, spores somewhat elevated, bilocular.

Usually it extensively and injuriously affects the leaves and stems of Podophyllum, attracting the eye by its beautiful color.)

Represented by four pieces of leaves about 4 by 6 cm., mounted loose in a packet, which are well covered with large groups of æcia, and by an original packet containing a number of large fragments of

leaves, bearing æcia, which is labelled "*Æcidium Podophyllat* Lvs Sal & Beth."

The rust is the æcial form of the long-cycle, autœcious species, *Puccinia Podophylli* Schw. (see no. 2939), on *Podophyllum peltatum* L. The combination *Æcidium* (*Cæoma*) *podophyllatum* was made on page 309 of the later work.

*2889. 79. *C. A. tenue*, L.v.S., rather rare on leaves of *Eupatorium ageratoides*, Bethlehem.

C. spots yellowish, evanescent, very delicate. Pseudoperidia sparse, slightly elevated, but, what is peculiar, erumpent on both surfaces, closed on the upper, open on the under. Spores pale.

Represented by a mounted portion of leaf, cut 3.5 cm. square, bearing six or eight groups of æcia, and by an empty packet, which is labelled inside "*Æcidium tenue* Nobis In fol ignot Deetwiler," and afterward "*Eupat. agerat*" substituted for "ignot," and is labelled outside "*Æcidium tenue* in fol *Eupat ageratoid* Dettyler."

This is the æcial form of *Puccinia tenuis* (Schw.) Burrill, an autœcious rust. The name is written *Æcidium* (*Cæoma*) *tenue* on page 309 of the same work.

*2890. 80. *C. A. Euphorbiæ hypericifoliæ*, L.v.S., frequent on leaves of *E. hypericifolia*, Salem and Bethlehem. It is not identical with *C. Euphorbiatum* Lk., nor does it make the leaves degenerate.

C. spots small, deep purple on the upper surface, yellowish on the lower. Pseudoperidia aggregated, subconically elevated, and somewhat excavated. Spores orange.

Although this number is starred and the earlier work is not directly cited, yet the naming of Salem as a locality undoubtedly has reference to Syn. Car. 455, which in fact must be considered the basis of Schweinitz's new name.

(455. 26. [*Æcidium*] *Euphorbiæ*. Here and there on the leaves of *Euphorbia hypericifolia*, but does not make them degenerate.)

Represented by a mounted fragment of a leaf, about 1 cm. square, well covered with æcia, and by an empty packet labelled "*Æcidium Euphorb. hypericif* Salem."

The rust is the æcial stage of *Uromyces proëminens* (DC.) Pass., and the host is *Chamæsyce Preslii* (Guss.) Arth. (*Euphorbia Preslii* Guss.), which passed under the name of *E. hypericifolia* in Schweinitz's time. Link's *Cæoma Euphorbiatum* is an entirely different species, being the æcial stage of a heterœcious form. On page 309 of Schweinitz's later work the name is changed to *Æcidium* (*Cæoma*) *Euphorbiæ hypericifoliæ*.

- *2801. 81. C. A. Houstoniatum, L.v.S., rather rare, but where occurring very copious on stem, leaves and peduncles of *Houstonia cœrulea*, Bethlehem.
C. without distinct spots. Pseudoperidia elevated, pale, subconic, apex contracted, and somewhat excavated. Spores orange. The infected and somewhat degenerate plants, nevertheless, flower.

Represented by three or more entire plants mounted loose in a packet, all considerably drawn, but a few with flowers, and by an original packet containing many rusted plants, which is labelled "*Æcidium Houstoniatum* LvS Beth."

The rust is the æcial stage of *Uromyces houstoniatus* (Schw.) Sheldon, having telia on *Sisyrinchium*, as proven by cultures. The combination *Æcidium* (*Cæoma*) *houstoniatum* is made on page 309 of the same work.

- *2892. 82. C. A. Claytoniatum, L.v.S., on *C. virginica* from New York. Communicated by Dr. Torrey.
C. almost simple and without spots, occupying the entire leaf. Pseudoperidia broad, sparse. Spores orange.

Represented by a mounted stem, 5 cm. long, with one unopened flower and two leaves, the leaves covered with æcia, and by an original packet containing one narrowly linear leaf, 6 cm. long, and labelled "*Æcidium Claytoniat* LvS Torrey."

A rather common rust, being the æcial stage of *Puccinia claytoniata* (Schw.) Peck. Schweinitz made the combination *Æcidium* (*Cæoma*) *claytoniatum* on page 309 of the same work.

- *2893. 83. C. A. Pyrolatum, L.v.S., on the under side of the leaves of *Pyrola rotundifolia*. Dr. Torrey.
C. without spots. Pseudoperidia sparse, occupying the whole leaf, but not transforming it, pulvinate-elevated, pale, or orange with

the spores. Finally these having fallen out *Peziza*-form cavities are left in the leaf.

Represented by half of a leaf, nearly 4.5 cm. broad, mounted, which is thickly covered with uredinia, and by an empty packet labelled "*Æcidium Pyrolatum* LvS in *P. rotundifol* Torr."

The rust is the uredinial stage of *Melampsoropsis Pyrolæ* (DC.) Arth. (*Chrysomyxa Pyrolæ* Rostr.), but was naturally mistaken for an *Æcidium* by Schweinitz, as it possesses catenulate spores. The host may have been *P. uliginosa* Torr., rather than *P. rotundifolia* L. The name *Æcidium (Cæoma) pyrolatum* is used by Schweinitz on page 309 in the same work.

*2894. 84. *C. A. Myricatum*, L.v.S., on leaves and especially on petioles of *Myrica cerifera*, communicated to me from New York by my friend Dr. Torrey.

C. spots on strongly swollen petioles, dark purple, black where dry, and out of the spots project the dense pseudoperidia, rather large, widely open, brown, filled with yellowish spores.

Represented by a mounted specimen, consisting of a terminal portion of stem, 2 cm. long, with four leaves attached, three being somewhat over 4 cm. long and 18 mm. wide, and with an abundance of æcia on the hypertrophied terminal bud, 2.5 cm. long, and by an original packet containing 3 cm. of stem with four leaves attached but without æcia, which is labelled on the inside "*Æcidium Myricæ* on *Myrica cerifera* L.," and on the outside "*Æcidium Myricatum* LvS in *Myr. cerifera* Torrey."

This is the æcial form of *Gymnosporangium myricatum* (Schw.) Fromme (*G. Ellisii* Farl.), as proven by cultures, the telia of which occur on *Chamæcyparis thyoides* (L.) B. S. P. The name is changed to *Æcidium (Cæoma) myricatum* on page 309 of the same work.

*2895. 85. *C. A. Osmundatum*, L.v.S., found on the fronds of *Osmunda spectabilis* and communicated by Torrey, but in drying so destroyed, that it is not possible correctly to describe it: the species nevertheless evidently distinct: spores ferruginous.

Represented by a narrowly triangular, lateral part of frond, 2.5 cm. long, blackish purple, mounted, and by an empty packet labelled "*Æcid?* *Osmundatum* in *O. spectab* Torrey." Schweinitz used the

name *Æcidium* (*Cæoma*) *osmundatum* on page 309 of the same work.

The structure of this fungus is not evident, although there is an abundance of globoid, brown spores present. The spores are 13–16 μ in diameter, and echinulate or verruculose. They resemble smut spores, but Clinton in his monograph of the Ustilaginales in the North American Flora (7:24. 1906), where it is mentioned as *Ustilago Osmundæ* Peck, excludes the species from that order and suggests that it may be a Hyphomycete. The latest name is *Mycosyrinx Osmundæ* Peck (*N. Y. State Mus. Rep.*, 1911, page 43).

*2896. 86. *C. A. Pyratum*, L.v.S., rather rare on leaves of *Pyrus coronaria*, Bethlehem. By no means identical with *C. Roestelites*.

C. spots on upper surface, orbicular, red, on the border ochraceous, center blackish. On the lower side there appear pseudoperidia very densely crowded, subconcentric, only a little elevated, margin beautifully multifid-fimbriate; the parts straight, not at all revolute, divergent, pale. Spores fuscous.

Represented by one oblong leaf, 3.5 cm. long and 1.5 cm. broad, broken across the middle, and mounted loose in packet, bearing numerous æcia on a somewhat hypertrophied spot, and by an empty packet labelled on the inside "*Cæoma* (*Ræstelia*) *coronarium* LvS Salem in *Pyr. coronar.*," with "*Æcid*" later substituted for *Ræstelia*, and on the outside "*Æcidium Coronarium* LvS in *Pyro conar. Salem.*"

The leaf is clearly that of *Malus coronaria* (L.) Mill. (*Pyrus coronaria* L., *P. angustifolia* Ait.), the rust being æcia of *Gymnosporangium Juniperi-virginianæ* Schw. To the mounted specimen is attached another packet containing a little larger, more lanceolate leaf, with numerous æcia of the same sort, bearing an inscription by Dr. W. G. Farlow, saying it is from the Herb. Curtis, on *Pyrus angustifolia*, Society Hill, N. C., no. 1226, and corresponds with Schweinitz's type of *A. pyratum*. The name *Æcidium* (*Cæoma*) *pyratum* is given on page 309 of the same work.

*2897. 87. *C. A. sambuciatum*, L.v.S., Syn. Car. 441, frequent on petioles and leaves of *Sambucus canadensis*, also Bethlehem. A further diagnosis follows.

C. spots intumescent, often very large (i. e. 2 inches) on petioles,

rather pale. Pseudoperidia large, dense, elevated, orange or pale, margin fuscous. Spores orange-fuscous, becoming de-colored. All much smaller on the leaves—pseudoperidia densely aggregated.

(441. 12. [*Æcidium*] *Sambuci* Sz.

A. maculiform, large, thick, contorting the leaves, orange, becoming white, peridia minute, and spores simple, pale.

Chiefly on the larger veins on the leaves, and on the petioles of *Sambucus Canadensis*. It distorts the leaves. Color orange-saffron; peridia sparse, spore-mass pale yellowish white.)

Represented by parts of two compound leaves and bits of hypertrophied rachis, mounted loose in a packet, showing numerous small groups of æcia, together with an original packet containing fragments of two leaves, also bearing small groups of æcia, labelled on the inside "*Æcidium Sambuci* In *Samb canad.* Sal & Bethl," and on the outside "*Æcidium Sambuciatum* LvS Bethl."

This is the æcial condition of *Puccinia Sambuci* (Schw.) Arth. (*P. Bolleyana* Sacc.), a common rust in the eastern United States, having telia on *Carex*. The asterisk before this number is a typographical error. The name *Æcidium (Cæoma) sambuciatum* is given on page 309 of the same work.

2898. 88. C. A. *Urticatum*, Lk. n. 169, Syn. Car. 436, very rare on *Urtica*. Salem, also at the same place on *Cynoglossum amplexicaule*.

(436. 7. [*Æcidium*] *Asperifolii*. Rather rare on *Cynoglossum amplexicaule*.)

Represented by neither a specimen nor an original packet at Philadelphia or in the Michener collection at Washington, or in the Herb. Curtis at Harvard University. *Cynoglossum virginicum* L. (*C. amplexicaule* Michx.) is not known to bear a rust. Neither is any rust known on *Urtica* so far south as North Carolina, although æcia are common north of the 39th parallel of latitude.

The association of *Urtica* and *Cynoglossum* probably is carried over from European observations as given in the work by Albertini & Schweinitz (l. c., p. 117). It is probable that some appearance of the leaves misled Schweinitz into thinking that he had found in America the same rusts he had observed in Sax'ony.

γ Subgen. RÆSTELIA or CERATITES.

2899. 89. C. R. *Cylindrites*, Lk. n. 172, Syn. Car. 432, under this name are included the following *Cæomata*, perhaps to be separated as species.
- α . C. *Cratægi punctatæ*, pseudoperidia divergent fibrous, swollen in the middle—white. Pennsylvania.
 - β . C. *Cratægi arborescentis*, spots small, red, pseudoperidia not fibrous, of various forms, fuscous-red. Near Fayetteville, Carolina.
 - γ . C. *Oxyacanthæ*, very large, very frequent near Philadelphia in hedges.
 - δ . C. *Mali*, on leaves of *Pyrus malus* and *coronaria*, spots small but effuse. Pseudoperidia minute.
- (432. 3. [*Æcidium*] *Cratægi* var. *Oxycanthæ*. A rare species on leaves of various *Cratægi*.)

Represented in each of the four forms by specimens and original packets from which it is possible to show that Schweinitz's surmise was right, that they belonged to four distinct species.

α . Represented by one leaf, 8 cm. long, of what is probably *Cratægus punctata* Jacq., mounted, bearing six groups of æcia, and by two smaller but similar leaves, about 6 cm. long and 4.5 cm. broad, with no mature æcia, in the original packet, labelled inside "Ræstelia (cornuta) oxyacanthæ In Crat. pyrifol Bethl," with "cornuta" crossed out, and "Cæoma cylindrites" written above, and outside labelled "Cæoma (Ceratites) *Cratægi punctatæ* Bethl aff. penicillat."

The rust proves by microscopic examination to be the æcia of *Gymnosporangium globosum* Farl.

β . Represented by a mounted leaf, 4.5 cm. long and about same width, of what is probably *Cratægus viridis* L. (*C. arborescens* Ell.), bearing four groups of æcia, and by half of a similar leaf with one group of pycnia, in the original packet, labelled outside "Cæoma (Ceratites) *Æcidium Cratægi arborescentes* Fayetteville." Half of a similar but smaller leaf, with one group of æcia, is in the Michener collection at Washington, property of the U. S. Department of Agriculture.

This æcial rust is that of the very distinctive southern species *Gymnosporangium hyalinum* (Cooke) Kern, whose telia are not yet known.

γ . Represented by a large, 4.5 cm. broad and originally much

longer leaf, mounted loose in a packet bearing five large, circinating groups of æcia, and by a small fragment of leaf about 3 cm. long, bearing æcia, in the original packet, labelled inside "Ræstelia oxyacanthæ α in Crat. oxyacant prope Philadelphia," and above this written later "Cæoma cylindrites," and labelled outside "2 Cæoma (Ceratites) cylindrites oxyacanthæ in Hedgerows Philad. vulgatis-sima."

This æcial rust observed by Schweinitz to be very common, on what was doubtless the English hawthorn (*Crataegus Oxyacantha* L.) and thought distinctive, was not again recognized until a trip by Dr. Frank D. Kern and the senior author to South Carolina in March, 1910, brought it to light. It belongs to *Gymnosporangium trachysorum* Kern, having telia on *Juniperus virginiana*.

8. Represented by one large, 5 cm. broad, and originally 10 cm. long, strongly pubescent leaf of the cultivated apple, bearing numerous small groups of æcia, one half, 4 cm. long, being mounted, and the other half, 5 cm. long, in the original packet, which is labelled inside "Ræstelia cancellata In Pyro coronario Salem," with all but the first word afterward crossed out, as if it were an error, and " β penicillatum var Mali" substituted, and added below "var. in Malo Bethl," and still later there was written above "Cæoma cylindrites," while on the outside the packet was labelled "2 Cæoma (Ceratites) cylindrites β penicillat in Pyr. Malo Beth."

The rust proves to be the æcial stage of *Gymnosporangium Juniperi-virginianæ* Schw. and on the common apple *Malus Malus* (L.) Britton (*Pyrus Malus* L.).

The entry in the North Carolina list, no. 432, is not represented by a specimen, and is too indefinite to be associated with any certain species, unless the form β be considered to cover it.

2900. 90. C. R. Roestelites, Lk. 173. Æcid. cancellatum, Syn. Car. 433 [error for 431]. In Bethlehem in an old orchard rejoicing in huge trees of *Pyrus malus*. In late autumn I have seen some of these trees, for 6-7 years, so covered by this fungus that the leaves appear red from a long distance.

(431. 2. [Æcidium] cancellatum. Very rare, only once on pear leaves.)

Represented by two sets of very unlike leaves, part of each being

mounted. One of these consists of parts of two apple leaves, cut lengthwise, 5 or 6 cm. long, mounted, bearing many small groups of æcia, and two similar pieces of leaves in the original packet, which is labelled "Cæoma Æcid. Ræstelites cancellat in Pyro malo arbores maximas ad mortem ægens 1829 Bethl." The other consists of two ovate pear leaves (*Pyrus communis* L.), 6 cm. long, mounted, and two similar, smaller leaves with another fragment in the original packet, each leaf bearing one to three large groups of æcia, the packet being labelled "2 Cæoma (Ceratites) Æcidium Ræstelites cancellat in Pyro Bethlehem."

The æcia on the apple leaves belong to *Gymnosporangium Juniperi-virginianæ* Schw., and those on the pear leaves belong to *G. globosum*.

2901. 91. C. R. Fraxinites, L.v.S., Syn. Car. 430, Lk. 170, Æcidium fraxini. Rather to be placed here; here and there; Bethlehem, on ash leaves.

(430. 1. [Æcidium] Fraxini Sz.

A. peridia elevated into a depressed chestnut-colored cone, at length splitting into the broad lacinia. It makes round chestnut spots on the leaves, prominent beneath, flat above, surrounded by a fuscous margin.)

Represented by two lengthwise halves, 1.5 by 6 cm., of broadly lanceolate leaflets, mounted, together bearing thirteen round groups of æcia on much swollen dark spots, but too young to show open peridia, and by an empty packet, labelled inside "Ræstelia Fraxini In Frax. Salem," with a later addition above "Cæoma Ræstelites *Fraxinitum*," with "Ræstelites" afterward crossed out, and labelled on the outside "Æcidium (Ceratites) *Fraxinites* LvS Salem & Beth."

The rust is the æcial form of *Puccinia fraxinata* (Link) Arth., on species of *Fraxinus*, having its telia on the marsh grass, *Spartina*.

[*]2902. 92. C. R. Botryapites, L.v.S. Very rarely observed on leaves of *Aronia botryapium*, Bethlehem; but where it occurs, rather frequent.

C. entirely distinct—spots yellowish-buff, somewhat effuse. On the under side the pseudoperidia appear central, aggregated as tubercles, globose, yellowish-green, at first obtusely conic and partly closed, at length somewhat open and much fimbriated at the opening, the divisions chestnut-brown, flexuous. Spores scanty, dark. Pseudoperidia few, even at times single.

Represented by four leaves, one of them 4 by 6 cm., the others trimmed down to that size from larger leaves, mounted loose in a packet, bearing seven characteristic galls, and by an original packet with eight similar leaves, 4-7 cm. long, having bleached spots but no rust, which is labelled "*Æcidium* (*Ceratites*) *Botryapii* LvS Bethl 1830."

The rust is the æcial stage of *Gymnosporangium botryapites* (Schw.) Kern. At page 310 of the same work Schweinitz changed the name to *Ceratites* (*Cæoma*) *botryapites*. The asterisk was erroneously omitted from this number.

δ. Subgen. PERIDERMIMUM.

2903. 93. C. P. Pineum, Lk. 175, Syn. Car. 456. In Pennsylvania near Philadelphia and elsewhere, not rare. Specimens ample, a foot long, found by me on the trunk itself of *Pinus inops*, suggesting a resemblance to *Gymnosporangium Juniperini*.
(456. 27. [*Æcidium*] *Pini*. Rare with us, and only on young leaves.)

Represented by two specimens. One of these consists of the section of a woody gall, 3 cm. across, mounted, with an empty packet, labelled "*Cæoma Peridermium Pini in Ligno Philad.*" A similar portion of a gall is in the Michener collection at Washington, property of the U. S. Department of Agriculture.

The other consists of about a dozen slender leaves from a 2-leaved pine, none full length, now about 5.5 cm. long, mounted loose in a packet, bearing a few æcia, with an empty packet, labelled "*Cæoma Peridermium Pini in acubus Salem.*"

Microscopic examination shows the woody form to be *Peridermium cerebrum* Peck, the æcial stage of *Cronartium Quercus* (Brond.) Schröt., and the leaf form to be *P. intermedium* Arth. & Kern.

- *2904. 94. C. P. germinale, L.v.S., very rare on the fruits of roses. Communicated to me by Mr. Collins.
C. pseudoperidia very long, cylindric, somewhat compressed, at length white, fimbriate, divisions cleft to the bottom, free. Spores effuse, pale. Pseudoperidia rising from little pits in the fruit, without any spot, usually three lines long.

Represented by a single oblong fruit, 1.5 cm. long, bearing many long and colorless peridia, and by the original empty packet labelled "Cæoma Peridermium *germinale* LvS in germinib. Rosæ Collins."

Although the fruit has considerable resemblance to a mummied rose hip, yet it is certainly the fruit of some species of *Cratægus*, and the fungus is the æcial stage of *Gymnosporangium germinale* (Schw.) Kern (*G. clavipes* Cooke & Peck). The name is given as *Peridermium* (*Cæoma*) *germinale* on page 312 of the same work.

Genus 212. PUCCINIA Lk. and DICÆOMA Fr.

2905. 1. *P. Graminis*, Lk. n. 1, Syn. Car. 492. Very common also in Pennsylvania on grasses.

(492. 7. [*Puccinia*] *Graminis*. Frequent on the culms of grasses, especially *Andropogon*.)

Represented by the original packet containing a crumpled leaf, and some fragments of stem and sheaths, all apparently of wheat, *Triticum vulgare* Vill., bearing blackish, open telia of *Puccinia poculiformis* (Jacq.) Wettst. (*P. graminis* Pers.), together with six or seven parts of conduplicate leaves, about 3 mm. wide, the pieces being from 6 to 15 cm. long, and heavily covered with dark brown or blackish telial sori. The narrow leaves are undoubtedly some species of *Carex*, and the rust some species other than *P. poculiformis*, but the identity of neither rust nor host has been definitely determined. The packet is labelled "*Puccinia Graminis cerealis* Germ. Sal. Beth."

One of the pieces of sheath bears a small strip of gummed paper across the middle, showing that it had originally been attached to a sheet (see Shear, *U. S. Dept. Agric. Bull.*, 380, p. 6, Jan. 15, 1917). The writing on the packet appears to have been done all at one time. It is, of course, impossible to say definitely if the material in the packet is wholly American, or partly obtained in Germany, as the labelling might indicate, but from the appearance it may be inferred that it represents two collections, both from this country.

*2906. 2. *P. striola*, Lk. n. 2, on various Cyperaceæ and grasses. Bethlehem.

Represented by the original packet containing a dozen or more short pieces, 1-6 cm. long, of a *Juncus*, probably *J. effusus*, bearing

uredinia and telia, the spores being those of *Uromyces Junci-effusi* Syd. The packet is labelled "2 *Puccinia Striola* Beth," the "2" indicating that the original collection had been divided into numbered portions, of which no. 2 only had been retained.

2907. 3. *P. Arundinariæ*, L.v.S., Syn. Car. 487, Lk. p. 68 in a note. Very good species, also on *Miegia* (*Arundinaria*) cultivated in the Bartram Gardens, Philadelphia.

(487. 2. [*Puccinia*] *Arundinariæ* Sz.

P. rather large, elevated, pulvinate (not surrounded by the epidermis), blackish-brown, spores oblong, bilocular, pedicel long.

Rather rare on leaves of *Arundinaria*. Of the size of a mouse dropping, beautifully scattered over the leaves. Cells of the spores equal to each other, color under a lens yellow, pedicels longer than the spore, radiately divergent, white, pellucid.)

Represented by an original packet containing a part of a leaf, 1 by 5 cm., which bears three telial sori in a row, two being empty of spores. The single sorus with spores is prominent, oblong, and dark brown or blackish. The packet is labelled "*Puccinia Arundinariæ* LvS Salem."

The rust still bears the name given it by Schweinitz. Its æcial form has not yet been discovered.

*2908. 4. *P. punctum*, Lk. n. 3, on *Carex* and *Scirpus*, Bethlehem.

Represented by two packets, one containing *Carex* and the other *Scirpus*, both rusted, together with a duplicate packet of the latter. One packet has a dozen or more, rather soft, crumpled leaves with a few stems, all heavily rusted, labelled "*Puccinia graminis* var. *hortensis* Beth," and afterward *graminis* crossed out and "*Punctum*" substituted. The rust proves to be the telial stage of *Puccinia Grossulariæ* (Schum.) Lagerh., and on some species of *Carex*.

Another packet contains twenty-five or more pieces of leaves, 3-9 cm. long, of what appears to be *Scirpus cyperinus* (L.) Kunth, abundantly rusted, labelled on the inside "*Puccinia Caricicola* LvS Beth," with "*Puccinia punctum* Lk" added later, and on the outside "*Puccinia punctum* Beth in *Caricibus*." The rust is that of *Puccinia angustata* Peck, being the telial stage, only a few uredinio-spores with their two superequatorial pores being found.

A duplicate packet of the last contains two pieces of similarly rusted leaves, about 3.5 cm. long, and is labelled "5 *Puccinia punctum* Lk caricicola LvS."

*2909. 5. *P. Scirpi*, Lk. n. 4, on various *Scirpi*, Bethlehem.

Represented by the original packet, containing very scanty shreds of leaf blades or sheaths, some of them 3-6 cm. long, and labelled on the inside "*Puccinia Scirpi* Beth 1826," and on the outside "2 *Puccinia Scirpi* Beth." The rust is clearly the telial stage of *Puccinia angustata* Peck, and the host is doubtless *Scirpus cyperinus* (L.) Kunth. It is entirely different from genuine *P. Scirpi* Link.

*2910. 6. *P. Sorghi*, LvS., frequent on the leaves of *Sorghum* and *Zea* cultivated.

P. without spots. Sori broad, difform, variously lobed, at first covered by the epidermis, at length naked but surrounded at the margin, and then the epidermis lacerate. Sori often also as if lobed from the center—2-4 lines long and broad. Larger sori occur on the nerves of the leaves. Spores blackish, large, shortly pedicelled.

Represented by some twenty-five pieces, 1-3 cm. wide and 3-8 cm. long, of leaves of Indian corn, abundantly covered with telia, contained in the original packet, which is labelled "*Puccinia Sorghi* LvS Lititz," with a later addition of "& Zeæ."

The leaves in the original packet are all without question those of *Zea Mays* L., and the rust is the one common to that host. One can only surmise why Schweinitz called the rust *P. Sorghi*, and said it was on *Sorghum*, a genus which has never been known to harbor the rust. But it would seem from the labelling of the packet that Schweinitz thought at first he had to do only with a *Sorghum* rust, and afterward found it was certainly on *Zea*, so assumed that it was on both kinds of hosts.

Because of the inappropriateness of the specific name, some taxonomists have adopted some other name, but most authorities still use Schweinitz's original name on the ground of priority. The alternate stage has been found by cultures to occur on species of *Oxalis*.

- *2911. 7. *P. Andropogi*, L.v.S., very frequent in autumn on leaves and culms also sheaths of various species of *Andropogon*, Bethlehem.

P. spots obscure, sori densely aggregated, elevated, fuscous, obtuse, linear, short. Spores fuscous. Although not confluent, yet occupying almost the whole leaf.

Represented by an original packet containing four or more stems and many leaves in pieces 7–10 cm. long, bearing an abundance of telia, labelled “*Puccinia in Andropogi* LvS.” The host is undoubtedly *Andropogon scoparius* Michx., and the rust still bears Schweinitz’s name, although generally written *P. Andropogonis*.

The two methods of writing the specific name indicate a difference in the method of forming the genitive of this and similar Latinized Greek words, common among classical writers of the very early as well as more modern times. The longer form is now generally adopted.

- *2912. 8. *P. emaculata*, L.v.S., here and there on leaves of *Panicum*, especially *Panicum pubescens* in fields, Bethlehem and Philadelphia.

P. entirely without spots; at first the sori are all covered, rather few, sparse, erumpent; later often confluent, minute, short, narrow, parallel, mostly acuminate at both ends. Spores very dark, rather small; immersed in water, brownish.

Represented by an original packet containing five fragments of grass leaves, 1–2 cm. wide by 2–10 cm. long, with a scanty showing of telia. The packet is labelled “*Puccinia emaculata* LvS in *Panico pubes.* Bart Gard.” The leaves are somewhat pubescent and considerably weathered. They can scarcely be the leaves of *Panicum pubescens* Lam., but rather are those of the more widely diffused *P. capillare*, judging from the soft pubescence, and from the general association of the rust. A portion of the Schweinitz collection has been seen by Prof. A. S. Hitchcock and by Mrs. Agnes Chase, the eminent agrostologists of Washington, D. C., who pronounce the host to be *P. capillare*.

- *2913. 9. *P. Junci*, L.v.S., on culms of *J. effusus*, Bethlehem, frequent.

P. scarcely with any spots; sori irregular, erumpent, somewhat covered by the epidermis, rather broad, applanate. Spores large, blackish brown.

Represented by an original packet, containing three pieces, 5–7

cm. long, from a terete stem split lengthwise bearing a few sori. It is labelled "*Puccinia Junci* LvS in *J. effuso* Beth." The teliospores are one-celled, and together with the few urediniospores seem to agree with later collections on the same host, now called *Uromyces Junci-effusi* Syd.

*2914. 10. *P. Windsoriae*, L.v.S., on leaves of *Windsoria* (*Poa*) *quinquedentata*, Bethlehem.

P. spots yellowish, at length evanescent. Sori long, linear, undulate, prominent, erumpent from the epidermis, not confluent. Spores compact, from purple to dark fuscous, long pedicellate.

Represented by an original packet containing ample material, consisting of parts of nine leaves, 3–10 cm. long, and four stems, 7–12 cm. long, well covered with telia. It is labelled "*Puccinia Windsoriae* LvS in culm & fol *Poæ* quinquedent Beth."

The rust still bears the name given to it by Schweinitz, but it has been impossible to trace the origin of the name of the host. No such specific name is known under *Poa* or *Windsoria*. Professor A. S. Hitchcock has suggested that it was a slip intended for *quinquifida*, a specific name used under *Poa* by Pursh, but never transferred to *Windsoria*. Neither name is given in Muhlenberg's "Catalogue," but he does have *Poa seslerioides* Michx. (*P. flava* L.), which is clearly the host in question, now called *Tridens flavus* (L.) Hitchc.

*2915. 11. *P. Zizaniae*, L.v.S., on the fallen leaves of *Zizania*. Kaign's Point, near Philadelphia.

P. without spots, minute, at first covered, at length linearly erumpent, the epidermis persistent about the margin of the sori; sori elongate, abbreviate, dark, held to the light somewhat fuscous. Spores loose, usually scattered about, short pedicelled, delicate, not much smaller than in related species.

Represented by an original packet containing two very small shreds of much weathered leaves 1–1.5 cm. long, bearing a few telial sori. It is labelled "*Puccinia Zizaniae* LvS Kaines Pt."

The fragments remaining of this collection are so very scanty that it seemed at first that no certain conclusion could be reached as to the identity of either host or fungus. The slightly reddish tint,

the character of the surface, the veining, and the rough edges show that these leaves could not have been those of *Zizania*. They do suggest *Andropogon*, however, and in spite of being weathered, they match well the leaves of *A. scoparius* and *A. virginicus*. Moreover, the teliospores, as well as a few urediniospores seen, agree fully with *Puccinia Andropogonis*, n. 2911. While the two *Andropogons* named can not be told apart by their leaves, we probably have to do with *A. virginicus* which occurs on damp soil about Philadelphia.

2916. 12. *P. Smilacis*, L.v.S., Syn. Car. 494, also in Pennsylvania.

(494. 9. [*Puccinia*] *Smilacis* Sz.

P. rather large, confluent, difform and stellate, dark fuscous, on *Smilax rotundifolia* occupying all of the somewhat dried leaves.)

Represented by an empty packet labelled "*Puccinia Smilacis* LvS Salem."

There is no doubt that this number is based upon the telia of the common southern *Smilax* rust, still called *Puccinia Smilacis* Schw.

2917. 13. *P. Polygonorum* Lk. n. 6, Syn. Car. 488, on *P. pennsylvanicum* and *P. virginicum*, also Pennsylvania.

(488. 3. [*Puccinia*] *Polygoni Pensilvanici* Sz.

P. rather small, aggregated, somewhat elevated, chestnut brown, opaque, at first closed, seated on pale spots, spores obovate-truncate.

Frequent on *Polygonum Pensylvanicum*; rendering the plants sterile. Spores bilocular, pedicel short; cells almost broader than long, fuscous under a lens.)

Represented by a packet containing two leaves, one about 3.5 by 5 cm., and the other somewhat smaller, bearing a few sori, which is labelled "*Puccinia Polygonorum P. virginica* LvS Salem & Beth."

The leaves are ovate-lanceolate, smooth with ciliate margins, and doubtless belong to *Tovara virginiana* (L.) Raf. (*Polygonum virginianum* L.). The other host named was also correctly determined, without question. The rust is now given the earliest name for it, *P. Polygoni-amphibii* Pers.

*2918. 14. *P. concentrica*, L.v.S., very frequent toward the end of autumn on half alive and dead leaves of *P. coccineum*, Bethlehem.

P. spots very large, confluent, bright red on upper surface, paler on the lower. Sori very crowded, aggregately concentric, at first

somewhat compact, black-shining, at length the spores loosened, minute, fuscous black. Possibly it is *P. Polygoni-amphibii* DeCandolle—but very certainly specifically distinct from the preceding.

Represented by a packet containing about ten fragments of leaves, some nearly complete, showing an abundance of telia, in part circinating about single uredinia. The packet is labelled "*Puccinia Polygoni coccinei concentricum omnino differt a P. Polyg virginici et aliis Bethl.*"

The leaves are broadly lanceolate, about 4 by 10 cm., and agree with those of a phanerogamic specimen at the Philadelphia Academy of Sciences, collected by Schweinitz, locality not given, and labelled by him *Polygonum coccineum*, which is now determined to be *P. emersum* (Michx.) Britt. The rust is *Puccinia Polygoni-amphibii*, as thought likely by Schweinitz, and differs from the preceding species only as influenced by the host.

*2919. 15. *P. bullata*, L.v.S., Syn. Car. 501, Lk. n. 8. In Pennsylvania, found very large, two to even three inches, especially on stems of *Vernonia noveboracensis*.

(501. 16. [*Puccinia*] *bullata* Sz.

P. very large, oblong, pulvinate, chestnut brown, surrounded by epidermis, spores very dense, oval, bilocular, long pedicelled.

Abnormal, erumpent from dried stem of various plants, e. g., *Ambrosia*, *Chenopodium*. Very large, usually an inch long and two lines thick, surrounded and often covered by the epidermis of the plant. The peduncles of the spores are five times as long, spores oval, short, the two cells equal.)

Represented by three packets. The principal packet contains four sections of stem, 3.5–5 cm. long, the largest being 8 mm. in diameter, and is labelled "*Puccinia bullata* LvS Salem & Bethl in *Caulibus variis*." The two duplicate packets, one with three, the other two, similar fragments of stem, are labelled, the first "*3 Puccinia bullata* LvS," and the second "*5 Puccinia bullata* LvS." Part of the same original collection is in the Fries Herbarium at Upsala, according to Lagerheim (l. c., p. 64), who renamed the species *P. longipes*, because the specific name had been antedated by Link (Obs., 1815).

All the fragments show very large sori, reaching 3 cm. long, characteristic of the rust on *Vernonia* when occurring on the stems. This is undoubtedly the same rust as the leaf form, recorded under no. 2926, as *P. Vernoniæ*, a name still generally applied to this rust. The leaf form has been grown by sowing spores from the large stem sori.

The asterisk before this number is a typographical error.

*2920. 16. *P. Pycnanthem*i, L.v.S., rather related to *P. Clinopodii*, frequent on *P. incanum*, Bethlehem.

P. spots purple, minute, persistent. Sori small, fuscous. Spores loose, long pedicelled.

Represented by an empty packet, labelled on the inside "*Cæoma* (*Uredo*) *Labiatarum* in *Pycnanth glauci* fol Beth," with *Uredo* crossed out and "*Puccinia*" substituted, and on the outside "*Puccinia Pycnanthem*i LvS in *Pyc incano* Beth."

The host can be accepted as correctly named, and the rust as identical with *Puccinia Menthæ* Pers.

*2921. 17. *P. compositarum*, Lk. n. 19, common, Bethlehem, especially on the stems and leaves of dead *Cnicus* or *Cirsium* (*P. caulicola*).

Represented by an original packet containing six sections of weathered stems about 5 cm. long, the largest being 5 mm. in diameter, and all bearing telia. The packet is labelled "*Puccinia caulicola* vere in caulib. *Cnici altissimi*," with "*compositarum*" afterward written in.

The cobwebby hairs on these stems indicate that they are thistles, and there is every reason to believe that they belong to *Cirsium altissimum* (L.) Spreng. (*Cnicus altissimus* Willd.) as labelled by Schweinitz. The rust agrees with *Puccinia Cirsii* Lasch. The reference to "*P. caulicola*" undoubtedly indicates the author's opinion that his material might possibly be referred to the European *Cæoma caulicola* Nees, which was originally found on stems of *Centaurea paniculata* (Syst. Pilze, 16, 1816). By later authors the specific name was transferred to *Puccinia* and applied to other forms.

- *2922. 18. *P. maculosa*, [L.v.S., not] Straus[s]. Bethlehem, here and there on leaves of *Prenanthes* or *Hieracium*. Entirely distinct from the preceding by the broad, white spots, spores much paler.

Represented only by an empty packet labelled "*Puccinia maculosa* LvS in fol. *Hieracii*." There is a specimen, however, in the Michener Collection at Washington, consisting of a glabrous, pale green leaf, a little more than 4 cm. long and 2 cm. wide, bearing four groups of telia, labelled "2922-18—Syn. Car. *Puccinia maculosa* Strau. in foliis *Hieracii* Beth. ex Herb. Schw." There is also a similar representation in the Herb. Curtis at Harvard University on "*Prenanthis* aut *Hieracii*," a small portion of which, through the kindness of Dr. W. G. Farlow, the writers have been able to examine. Both host and fungus from these two sources agree perfectly with the material published as 1855, Ellis & Everhart, "North American Fungi," on *Cynthia virginica* from Illinois, 1882, A. B. Seymour, and as 3413, Rabenhorst-Winter, "Fungi Europæi," on *Krigia virginica* (*Cynthia virginica*) from Missouri, 1885, C. H. Demetrio. A good description of the rust was given by Burrill in his "Parasitic Fungi of Illinois," p. 188. It is evident that Schweinitz was very uncertain about the name of the host as he calls it *Hieracium* on packets, and "*Prenanthes* or *Hieracium*" in the published account, and quite naturally so, if we consider it to be *Krigia* or *Cynthia virginica*, now called *Adopogon virginicus* (L.) Kuntze, for that plant has the aspect when growing that might well cause it to be considered under either genus. Even Muhlenberg must have been uncertain about it, as his catalogue either does not mention it, or merges it with some other species, although a common plant of the flora.

Strauss gave the name *Uredo maculosa* (*Ann. Wett. Ges.* 2: 101. 1810) to a European rust on *Prenanthes purpurca*, apparently including both uredinia and telia, with which no rust in America has been identified. The rust found by Schweinitz is a short-cycle form not known in Europe. The specific name *maculosa*, under the genus *Puccinia*, is, therefore, to be credited to Schweinitz.

2923. 19. *P. Helianthorum*, L.v.S., Syn. Car. 495, Lk. p. 74, clearly distinct—frequent on various *Helianthi*, and in Pennsylvania best developed on dead leaves. On cultivated *H. tuberosus*, it occupies the lower surface of almost all leaves.

(495. 10. [Puccinia] *Helianthi* Sz.

P. rather small, orbicular, aggregated, black, spores globoid-oval, bilocular, very long pedicelled.

Common on many *Helianthi*.—Spores fuscous yellow, pedicel white, pellucid.)

Represented by an original packet containing twenty or more fragmentary leaves, 1–4 cm. wide by 6–10 cm. long, and a leafy stem, 5 cm. long, bearing one mature flower head, the leaves richly supplied with telia. The packet is labelled “*Puccinia Helianthorum* LvS 1826.”

The leaves of this collection are lanceolate or ovate-lanceolate, and probably came from the upper part of the plant. Examination of the leaves together with the flowering head makes it certain that the host is *Helianthus tuberosus* L., and the date, “1826,” shows that the collection was made in Pennsylvania, doubtless at Bethlehem. The rust still generally goes by the name first given by Schweinitz, *P. Helianthi*, although his specific name for the æcial stage (no. 2871) has priority of place in the same publication and technically should replace it as *P. Helianthi-mollis*.

Schweinitz evidently inserted “clearly distinct” under this entry, and similar expressions in the following and other entries to emphasize his dissent from Link’s opinion (l. c.) that the species might be the same as the European *P. Syngenesarum* Link.

2924. 20. *P. Heliopsisidis*, L.v.S., Syn. Car. 493, Lk. p. 74, and Pennsylvania—entirely distinct.

(493. 8. [Puccinia] *Heliopsisidis* Sz.

P. rather irregular, aggregated, surrounded by the epidermis, chestnut brown, spores oval, elongate, long pedicelled, bilocular:

Frequent on dried leaves of *Heliopsis*, also on *Vernonia*.—Cells of the spores equal, septum situated exactly in the middle of the spore.)

Represented only by an empty packet, labelled “*Puccinia Heliopsisidis* LvS.”

The rust on *Heliopsis* is still known by the name given to it by Schweinitz. It has only been found on *H. helianthoides* (L.) Sweet. Although given as “frequent,” yet it is represented by only five collections in the Arthur herbarium, all from the Mississippi

region, three with æcia, one with uredinia, and only one showing telia. The species must be local, although widespread.

2925. 21. *P. Verbesinæ*, L.v.S., Syn. Car. 496, Lk. p. 74, not yet in Pennsylvania—good species.

(496. 11. [*Puccinia*] *Verbesinæ* Sz.

P. punctiform, sparse, fuscous black, spores ovate, bilocular, pedicel short.

On flourishing leaves of *Verbesina*, *Sigesbeckia* (Richweed).—Spores narrower at the apex than at the base, bilocular: cells equal. Not surrounded by the epidermis.)

Represented by an empty packet, which is labelled on the inside "*Dicæoma Verbesinæ* Salem," and on the outside "*Puccinia Verbesinæ* LvS Salem."

Schweinitz's name still holds good for the *Verbesina* rust of the region he explored. It most likely does not occur on *Siegesbeckia* (richweed), on which no rust has yet been found.

- *2926. 22. *P. Vernoniæ*, L.v.S., very common on *Vernonia*, Bethlehem.

P. without spots. By the rather pulvinate sori and by the beautiful rusty color of the spores it differs from *P. Helianthi*. It occurs also occasionally on *Helianthus*.

Represented by an empty packet, labelled "*Puccinia Vernoniæ* LvS in *Heliant ferrugin*."

This is without doubt the leaf form of the common *Vernonia* rust, the stem form of which Schweinitz had already named *P. bullata* (no. 2919). The rust does not occur on *Helianthus*, although occasionally the *Helianthus* rust simulates the one on *Vernonia*.

2927. 23. *P. Xanthii*, L.v.S., Syn. Car. 500, Lk. n. 23. Also frequent on leaves of *Xanthium* in Pennsylvania. Beautiful and conspicuous from a distance. Sori usually concentric and aggregated in the center of the spot.

(500. 15. [*Puccinia*] *Xanthii* Sz.

P. spots delicate, orbicular, pale, beneath fuscous brown with a pale margin, spores oblong, bilocular, pedicellate.

On lower surface of the leaves of *Xanthium strumarium*, in sandy places. Beneath it shows at first pale vesicles resembling the cells of the leaf, these being broken and encircled by the epidermis, the spores appear in a coherent fuscous pustule, yellow under a lens, the pedicel longer than the spore.)

Represented by an original packet, containing part of one leaf about 3 by 6 cm., bearing many groups of telia, which is labelled "Puccinia *Xanthii* LvS Sal & Beth."

A very common short-cycle rust still designated by Schweinitz's name.

- *2928. 24. P. *Helenii*, L.v.S., rather rare, but prominent, on leaves of *Helenium autumnale*, Bethlehem.
P. spots golden yellow, expanded, sori pulvinate, sparse, and close to each other, convex, at first brown, later beautifully chestnut. Spores rather large, compact.

Represented by a packet containing the tip of a stem, about 2 cm. long, with six small, sessile leaves attached, together with parts of three maturer, lanceolate leaves, the largest 2.5 cm. broad and 7 cm. or more long. The packet is labelled "Puccinia *Helenii* LvS Bethl." An empty duplicate packet is labelled "2 Puccinia *Helenii* LvS."

A careful study of this material leaves little doubt that the host is *Aster salicifolius* Lam., and that the rust is the common *Puccinia Asteris* Duby. The leaves of *Helenium* have a peculiar lower surface due to a sparse pubescence, quite unlike the smooth lower surface of the material in the packet, or of *Aster salicifolius* and of similar lanceolate-leaved species of the genus *Aster*. From an original specimen in the Fries Herbarium at Upsala, Lagerheim (*Tromsö Mus. Aarsh.*, 17:60, 1894) has given detailed characters as a good species, not remarking any error in the host. Even if the host had been *Helenium*, yet the rust would undoubtedly have proven to be the same species that occurs on *Aster*, judging by the description given and the relationship and characteristics of the hosts.

- *2929. 25. P. *Silphii*, L.v.S., sent from Carolina, on leaves of *S. trifoliatum*, by my friend Denke.
P. spots rather small, purple. Sori thick, pulvinate, confluent, aggregated, black. Spores compact, concolorous.

Represented by four small fragments of leaf, the smallest one, 1.5 cm. long, bearing a group of telia. The packet is labelled "Puccinia *Silphii* LvS in Sylph trifoliat Denke."

Both rust and host appear identical with those respectively that go under the same names at the present time.

*2930. 26. *P. Asteris*, L.v.S., a handsome species, frequent on leaves of *A. paniculatus*, Bethlehem.

P. spots flattened, bullate, yellow, not widely expanded. Sori very dense, subconcentrally placed, beautifully fuscous. Spores rather loose, concolorous.

Represented by a packet containing a short stem with three leaves attached and also by ten much crumpled, similar, ovate-lanceolate leaves, all with long, slender petioles, and all sparsely bearing telia. The packet is labelled "*Cæoma* (Ur) *Asterum* LvS Bethl in *Ast. paniculat*," with the first two words crossed out and "*Puccinia*" substituted.

The leaves are doubtless *Aster cordifolius* L., and the rust is the short-cycle form first given the name *Puccinia Asteris* by Duby in 1830, two years before the Schweinitz name was published. Doubtless the early collection on *Aster paniculatus*, this being its most common host, was entirely given away, leaving only a later collection on *A. cordifolius*.

*2931. 27. *P. Kuhniae*, L.v.S., common on the leaves of *Kuhnia*, Bethlehem.

P. without any spots. Sori amphigenous, pulvinate, densely aggregated, blackish brown. Spores rather large, loose, long pedicelled. A Phragmidium?

Represented by an original packet labelled on the inside "*Uredo Kuhniae* in *K. eupator* Bethl & Salem," with "*Uredo*" crossed out and "*Puccinia*" substituted, and on the outside "*Puccinia Kuhniae* LvS Beth." The packet contains a tiny fragment, 2 by 3½ mm., bearing a few large telial sori. The peculiar glands and hairs make the host unmistakable, and the amphigenous sori with their ellipsoid teliospores fully justify the record.

The rust is not common eastward, Schweinitz's record being the only one known to the writers east of Wisconsin and Indiana, although in the middle west, especially between Illinois and the foothills of Colorado, it is not infrequent. In the Carolina list *Kuhnia* is mentioned as host for a rust (see no. 2844), and the earliest label on the packet reads "Bethl & Salem," but the packet was probably

not labelled until after Schweinitz became a resident of Pennsylvania. We may safely assume that the packet with its fragment represents a collection made at Bethlehem, Pa. Unless this were true the asterisk before the number would have to be considered erroneous, and the omission of "Syn. Car. 478" unintentional. Furthermore, if Salem were the place where the collection was made, the record would have been *Salem & Bethl.*, as may be seen under nos. 2832, 2846, 2875, 2888, 2917, 2919, 2927, etc. Some observation at Salem may have been in mind, but with no specimen preserved.

*2932. 28. *P. investita*, L.v.S., frequent, observed with *Æcidium gnaphalium* on the tomentose leaves of *Gnaphalium polycephalum*, Bethlehem. Always hidden by the tomentum.

P. without spots; sori minute, sparse, roundish, very black, scarcely showing at first through the tomentum, sometimes aggregated-confluent. Spores compact, very dark. Surface of the sori as if furrowed.

Represented only by an empty packet labelled "*Puccinia investita* LvS in avers pag *Gnaphalii polycephali* cum *Æcidio vulgari* Beth." There is no reason to doubt that this record applies to the rust still passing under Schweinitz's name, *P. investita*, which possesses æcia and telia, and is identical with no. 2873, and now better called *P. gnaphaliata* (Schw.) Arth. & Bisby.

2933. 29. *P. Galii*, L.v.S., Syn. Car. 499, Lk. p. 76, a rare species but sufficiently distinct—not a *Sclerotium*.

(499. 14. [*Puccinia*] *Galii* Sz. (near *Sclerotium*).

P. erumpent, globose-ovate, dark fuscous, spores clavate, bilocular, short pedicelled.

On living leaves of *Galium purpureum*, but more perfect on dead ones, then a line long.—Tubercle-like it pushes up the epidermis, which surrounds it. Spores a little darker in color than those of *Puccinia graminis*.)

Represented only by an empty packet, labelled on the inside "*Dicæoma Galii* Salem," and on the outside "*Puccinia Galii* LvS Salem." There is no specimen of this number at Philadelphia, or in the Herb. Curtis at Harvard University or in the Michener Collection at Washington.

It is particularly unfortunate that no specimen is available to substantiate the record, as there is no other record of a *Galium* rust having been collected in North Carolina. The most southern collection in the Arthur herbarium is that of *Puccinia punctata* Link on *G. triflorum* made by Mrs. Emily Arthur at Salt Sulphur Springs, W. Va., in 1914, a locality on the opposite slope of the Allegheny Mountains to the northwest from Salem, N. Car. There is no other record than Schweinitz's of a rust on *G. purpureum* Walt., now referred to *G. pilosum* Ait., although it would not be an unlikely host for *P. punctata*. The tubercle-like emergence of the sori and their distinctly blackish color are sufficiently characteristic of the telia of *P. punctata* Link to make it probable that Schweinitz had this species in hand, although it must be a rare fungus in the Carolina flora.

*2934. 30. *P. Myrrhis*, L.v.S., on leaves and stems of *Myrrhis procumbens*, Bethlehem.

P. without spots. Sori dense, minute, surrounded by the ruptured epidermis, pulvinately applanate. Spores very loose, golden brown.

Represented by a scanty specimen, consisting of numerous very small fragments showing a few pale telia, in the original packet, which is labelled "*Puccinia Myrrhis procumb* LvS Beth."

Both urediniospores and teliospores are present in the specimen, and are characteristic for the species now called *Puccinia Pimpinellæ* (Str.) Mart. The host is clearly as named by Schweinitz *Chærophyllum procumbens* (L.) Crantz (*Myrrhis procumbens* Spreng.).

*2935. 31. *P. Bullaria*, Lk. n. 32, on stems of *Hyssopus nepetoides*, rare, Bethlehem.

Represented only by an empty packet labelled "*Puccinia caulicola* in *Hyssop. nepet. Bet.*," with second word crossed out and "*bullaria*" written in.

There is a specimen in the Michener Collection at Washington exactly answering the requirements of this number. It is a piece of smooth stem 4 cm. long, split lengthwise and originally 3 mm. in diameter. Protruding from a longitudinal fissure 2 cm. in length is a fungus-like growth, brown and bullate, that may be the early

stage of some ascomycete but is certainly not a rust. No spores were found. As the host is a labiate and not an umbellifer, Link's name could not in any case be applicable.

- *2936. 32. *P. anemones*, Lk. n. 33, very rare on leaves of *A. quinquefolia*, but most distinct, Bethlehem.

Represented only by an empty packet, which is labelled inside "*Dicæoma punctata* Deetw," with the later addition above of "*Puccinia anemones*," and on the outside "2 *Puccinia Anemones* Beth Deetwyler," and also a word preceding the last one which is not wholly legible.

There is practically no doubt that this number covers the rust on the host as stated, now called *Polythelis fusca* (Pers.) Arth.

2937. 33. *P. solida*, L.v.S., Syn. Car. 486. [as *P.*] *Anem. virginian*, frequent on leaves of *Anemone virginiana*, Salem and Bethlehem.

P. without spots. Sori sparse, rather large, so very compact that they appear solid, black. Spores at length somewhat loosened. Sori dispersed over the whole leaf, at first yellow and more or less impressed.

(486. 1. [*Puccinia*] *Anemones Virginianæ* Sz.

P. punctiform, sparse, chestnut brown, spores clavate, attenuate into a short pedicel, bilocular.

Spores under the lens yellowish-white; they pass into the pedicel so that it is not possible to distinguish where they begin.)

Represented by an empty packet, labelled "*Puccinia solida* LvS in *Anem. Vir.*"

A widespread and well-known species, still bearing the earlier name here given.

2938. 34. *P. circææ*, Lk. 43, Syn. Car. 491, common, and Bethlehem.
(491. 6. [*Puccinia*] *Circææ*, frequent on leaves of *Circæa*.)

Represented by a packet containing parts of three leaves, the best preserved being about 3 by 5 cm., and labelled "2 *Puccinia Circææ* Germ & B & S," with cancellation marks across "Germ." Two of the leaves are faded and pressed smooth, the third is natural green and crumpled by drying. The rust and host, undoubtedly *C. Lutetiana*, are common and widespread, although no other collection of the rust is yet known so far south.

2939. 35. *P. aculeata*, L.v.S., Syn. Car. 489. *P. podophylli*, likewise common on *Podophyllum* [in Pennsylvania]. Very distinct on account of the aculeate spores.

(489. 4. [*Puccinia*] *Podophylli* Sz.

P. rather large, subconcentric, chestnut black on yellowish spots, spores oblong, bilocular, aculeate.

Here and there on leaves of *Podophyllum*.—Spores oval, under a lens yellowish, the points prominent, straight. Pedicel not distinct, very short.)

Represented only by an empty packet, labelled "*Puccinia aculeata* LvS in *Podoph Sal & B.*"

Owing to Schweinitz's slip of the pen in calling the spores of *Æcidium Podophylli* (no. 2888) "bilocular," Link transferred that form to the genus *Puccinia*, which necessitated a new name for the present form, so he made a descriptive name from a very distinctive character (l. c., p. 79). Schweinitz adopts the name, but evidently considers himself responsible for the species, and, as in other such cases, does not cite Link's work. Schweinitz's earlier name is still in use for this rust.

2940. 36. *P. Lespedezæ procumbentis*, L.v.S., Syn Car. 497, Lk. p. 83, extraordinary species, and in Pennsylvania.

(497. 12. [*Puccinia*] *Lespedezæ procumbentis* Sz.

P. rather small, subpunctiform, sparse, somewhat fuscous, erumpent, spores oblong, bilocular.

Here and there on leaves of *Lespedeza procumbens*.—It lifts the epidermis of the lower surface of the leaf into blisters, which ruptured are white, pellucid. Spores with septum situated exactly in the middle of the spore, and the pedicel (white, rather long) is distinct from the spore.)

Represented only by an empty packet, labelled "*Puccinia Lespedezæ procumbent* LvS Salem."

The senior author in his first publication on the subject of rusts (*Amer. Nat.*, Jan., 1883, pp. 77-78) pointed out that doubtless Schweinitz was led into the error of describing the spores as bilocular by looking at the dry spores under a magnification of about seventy-five diameters. At any rate the microscopic details in Schweinitz's description can be attested in this way. The greatly thickened wall at the upper part of the teliospore, often equal to half the spore's length, under these conditions takes on the appear-

ance of an upper cell separated from the lower by a transverse septum. In reality the teliospores are one-celled, and the rust belongs under the genus *Uromyces*, as *U. Lespedeza-procumbentis* (Schw.) M. A. Curt.

2941. 37. *P. Lespedeza violaceæ*, L.v.S., Syn. Car. 498, Lk. p. 83, much more frequent on *L. violacea* than on *L. polystachya*, also in New Jersey.

(498. 13. [*Puccinia*] *Lespedeza polystachya* Sz.

P. rather small, punctiform, surrounded by the epidermis, black shining, spores oblong, attenuate at both ends, somewhat bilocular.

Frequent on the lower surface of the leaves.—Surrounded by the epidermis. Spores more elongate and attenuate into the pedicel, septum scarcely visible, it appears vaguely now near the apex of the spore, again lower. Color of the spores, under a lens, yellow.)

Represented by neither specimen nor original packet. The rust is an abundant one, and is considered by all recent mycologists to be identical with the preceding, *Uromyces Lespedeza-procumbentis* (Schw.) Curt., and to be both on *L. hirta* (L.) Hornem. (*L. polystachya* Michx.) and *L. violacea* (L.) Pers.

The elaborate but elusive description of this species, when taken in connection with that of the preceding number, illustrates the imperfect equipment possessed by Schweinitz and others of his time for the study of microfungi, and leaves us astonished at the large measure of success attained. The present number also illustrates the futility of long and cumbersome specific names for correctly designating a species. Before a decade had passed Schweinitz said that the rust which he specifically limited to *Lespedeza polystachya* was found by him "much more frequent on *L. violacea*." How much better it would have been to have designated this rust as *P. affinis*, or by some such simple appellation, and avoided bestowing a name that would be burdensome to other mycologists.

*2942. 38. *P. Phaseoli trilobi*, L.v.S., on leaves of *P. trilobus* sent from New York. Appears related to *P. fabæ*.

P. sori minute, hypophyllous, partly covered by the epidermis. Spores black, spots none.

Represented by an empty packet, which is labelled "*Puccinia Phaseoli* Newyk in *Phaseolo trilobo*." There appears to be no

doubt that this number belongs under *Uromyces appendiculatus* (Pers.) Fries, and on *Strophostyles helvola* (L.) Britton (*P. trilobus* Michx.).

*2943. 39. *P. Fabæ*, Lk. n. 45, on leaves of *V. faba*, Nazareth.

Represented by neither specimen nor packet. Doubtless the rust was *Uromyces Fabæ* (Pers.) DeBary, and on the host named, at that time a plant more often cultivated in America than at present.

*2944. 40. *P. Hyssopi*, L.v.S., on leaves of *H. scrophulariæfolius*, Bethlehem occasionally.

P. spots yellowish, effuse. Sori aggregated, compact, fuscous, somewhat circinate and undulately confluent with each other, at first blackish, small but occurring copiously upon the leaf. Spores fuscous, at length rather lax.

Represented by a packet, containing a stem, 4 cm. long, with two opposite and petioled leaves attached, and by parts of three other leaves, the largest being 2.5 cm. wide, bearing many groups of telia. The packet is labelled "*Puccinia Hyssopi* scrophul LvS Beth 26."

The host is now placed under *Agastache*, as *A. scrophulariæfolia* (Willd.) Kuntze, and the rust is identical with *P. verrucosa* (Schultz) Link.

*2945. 41. *P. Potentillæ*, L.v.S., not *Phragmidium*, Lk., on mature leaves of *P. canadensis*, on lower surface, Bethlehem.

P. sori minute. Spores fuscous, at length black, erumpent, short pedicelled. Spots almost disappearing.

Represented by an empty packet, labelled "*Puccinia Potentillæ*," with one other word, not deciphered.

The rust is undoubtedly the one often called *Phragmidium Potentillæ-canadensis* Diet. It was transferred to the genus *Kuehneola* by the senior author some time since, and again very recently to the genus *Frommea*, under which it is *F. obtusa* (Strauss) Arth.

*2946. 42. *P. Ari triphylli*, L.v.S., on lower surface of the leaves of *A. triphyllum*, Bethlehem.

P. spots pale, very broad, on the margins of the leaves. Sori large,

often confluent, at first covered by the epidermis, soon ruptured. Spores brown fuscous, loosely attached and Uredo-like but nevertheless a true Puccinia.

Represented by a packet containing two large leaflets, 8 by 15 cm., bearing several loose groups of telia, and labelled "*Puccinia Ari triphylli* Mauch Chunk."

This number is now called *Uromyces Caladii* (Schw.) Farl., and on *Arisæma triphyllum* (L.) Schott (*Arum triphyllum* L.), other stages of the life cycle being listed under nos. 2839, 2860 and 1861.

Genus 213. PHRAGMIDIUM.

It is worthy of note that I have never met with a *Phragmidium* in America on the leaves of *Rosa* or *Rubus*, but the following very common species without doubt belongs here.

2947. 1. *P. Hedysari*, L.v.S., Syn. Car. 503, frequently occurs on leaves of *H. paniculatum* and others, Bethlehem and Salem.

P. sori minute but thickly scattered over the whole leaf, resting upon the epidermis. Spores long pedicelled, pedicel articulate, pellucid, remainder opaque, ovate, obtuse, not cylindric, obscurely septate, not constricted at the articulations, fuscous black.

(503. 18. [*Puccinia*] *Hedysari paniculati* Sz.

P. punctiform, sparse, fuscous, spores ovate-globose, fuscous, pedicel very long, filiform, pellucid.

Frequent on the under face of the leaves of *Hedysarum paniculatum*. I see no septum in the spore. Pedicel filiform, pellucid.)

Represented only by an empty packet, labelled on the inside "*Dicæoma Hedysari paniculat* Salem," and on the outside "*Puccinia Hedysari panic Salem*."

If the genus *Uromyces* had been in use at the time, Schweinitz undoubtedly would have placed this species under it, certainly at first, for he says he could see no septum. What his idea of the genus *Phragmidium* was, it is now difficult to say, but the senior author has explained in the paper referred to under no. 2940, that when the teliospores are seen dry under low magnification "the pedicels being delicate cylinders collapse and twist like a ribbon, and what appear to be three or four joints in each pedicel are very dis-

tinctly shown" (l. c.), hence Schweinitz says "pedicel articulate." The earlier specific name is still retained, the species being *Uromyces Hedysari-paniculati* (Schw.) Farl., and on *Meibomia paniculata* (L.) Kuntze (*Hedysarum paniculatum* L., *Desmodium paniculatum* DC.).

Note.—The genera numbered 214–246 include the remainder of Series I and all of Series II–IV. Under Series IV, Sporodermei, the following species belong with the rusts.

Genus 241. SEIRIDIUM.

- *3084. 1. *S. marginatum*, Lk. p. 126, n. 1. Our plant, very common on *Rosa corymbosa* growing in inundated places, agrees exactly with Nees's illustration and description. But it is not the same in size; for usually it occurs on branches, living or half alive, with huge sori, very thick, two inches, encircling the branches, and often many sori joined together. Spores so large that they are clearly visible to the naked eye, or at least through a lens of very low power.

Represented by a mounted specimen, consisting of three rose stems, 4–6 cm. long and 6 mm. thick, well provided with large, blackish sori. No original packet was to be found. The rust is clearly the very distinctive *Earlea speciosa* (Fries) Arth. (*Phragmidium speciosum* Fries), on *Rosa carolina* L. (*R. corymbosa* Ehrh., *R. pauciflora* Muhl.).

- *3085. 2. *S. Similacis* [typographical error for *Smilacis*], L.v.S., here and there erumpent from the stems of *Smilax caduca* and other species, Bethlehem.
- S.* sori very long, confluent, yet much smaller, and not so thick [as in the preceding species]. Spores cylindric, dark fuscous, obtuse, pedicels very long, contorted, white.

Represented by neither specimen nor packet at Philadelphia. In the Michener Collection at Washington, there are two stems, one 5 cm. long by 5 mm. in diameter, and the other 4 cm. long and 3 mm. in diameter, with many long weak prickles and well covered with masses of telia. They are mounted and are labelled "Schw. Mss. *Seiridium obtusiusculum* on rosa, *Smilacis* Beth. ex Herb. Schw.," but without number.

The host is undoubtedly some species of *Rosa*, and may well be *R. virginiana* Mill., while the rust is undoubtedly *Earlea speciosa* (Fries) Arth. The appearance of this material corresponds to Schweinitz's description.

Genus 243. GYMNOSPORANGIUM.

- *3094. 1. *G. Juniperi*, Lk. p. 127, n. 1. Not frequent, but very distinct from *Podisoma Juniperi*, found near Easton, Pennsylvania, on *Juniperus virginiana*.

Represented by a mounted specimen, consisting of a woody stem, 11 cm. long and 8 mm. in diameter, with a fusiform swelling from which the sori have dropped away. The stem was broken into two unequal parts before mounting. No original packet has been found.

The rust is that of *Gymnosporangium germinale* (Schw.) Kern (*G. clavipes* C. & P.), of which the æcial form is given under 2904.

Genus 244. PODISOMA.

- *3095. 1. *P. Juniperi*, Link, p. 127, found by me on a single Junip. Sabina in this region—copiously developed.

Represented by a mounted specimen, consisting of a four-branched, woody stem, 5 cm. long, having a few subulate leaves each about 5 mm. long, and with a few, slender, corneous sori remaining, most of the telia having dropped out or been eaten by insects. No original packet has been found.

The rust is that of *Gymnosporangium clavariæforme* (Jacq.) DC., and the host is most likely *Juniperus communis* L., being the common juniper, and not the red cedar as the name used by Schweinitz would seem to indicate.

3096. 2. *P. macropus*, L.v.S., Lk. p. 127 [error for 128], wrongly under *Gymnosporangium* [in earlier work]. In the parts of North Carolina best known to me a rather rare fungus. In Pennsylvania very common, particularly affecting *Juniperus virginiana* that has suffered by much pruning, and commonly known by the name "Cedar apple," under which name it is offered in the market as a powerful, though imaginary, vermifuge remedy. Link expresses regret that I did not examine the structure of the underlying sporidochium. Now such things as were not dis-

cussed by me, upon this point, I gladly add here. In the first place this very puzzling base ought by no means to be regarded as a sporidochium, if by this term it is intended to designate the structure so called in *Podisoma Juniperi*. That body, which is gelatinous and composed of the interwoven stalks of the spores, corresponds exactly with the tremellose ligules of our *P. macropus*. On the other hand the basilar capitulum, the part in question, is of a wholly different nature. Never, moreover, is it wanting. In fact it always constitutes the first evidence for our fungus; showing itself in the earliest stage on the slender branches of *J. virginiana* of the size of a rather large pinhead, enlarging gradually, usually without altering the affected branch, and swelling into a more or less regularly turbinate and plicate capitulum,—reaching a diameter of an inch, or even two inches. Its texture when dry and old is fibrous-corky, as in *Fistulina* but not succulent-fleshy, as if composed of fibers radiating from the broadly obconic pedicel—otherwise presenting at the time a somewhat woody condition. The immature capitulum, on the other hand, may be easily cut like an apple, or even eaten. Externally it has an epidermis-like cortex from lilac to fuscous purple in color, entirely juiceless like the skin of an apple. Over the whole surface appear regular pits, polygonal or mostly pentagonal, at first merely applanate, soon impressed and umbonate; finally during wet weather, the cortex rupturing in the center, the ligular gelatinous sporidochia an inch long are protruded—bedecking all the trees during a rainy spring night as it were with the richest crop of ripe oranges. If the wet weather continues for some days, the ligules in this condition begin to dissolve. In the sunshine, however, the ligules are soon dried out—and they never again revive. The capitulum persists through the year. Old specimens are internally not unlike excrescences of trees. Yet never can a capitulum be found without ligules, at least at first, nor ligules without a capitulum. It is usual where trimmed juniper trees are forced artificially into a pyramidal or other shape for this fungus to attack them in incredible abundance—but according to my observations carefully made during ten years, such trees are not destroyed, nor do they appear even to be harmed. There are therefore many people, and not a few educated ones, who thoroughly believe this fungus to be the inflorescence or genuine fruit of the juniper. I am thoroughly convinced by careful study that the base has nothing to do with insect work. Yet it is not to be positively asserted that it is fungous. It seems to me to be a very abnormal growth, concerning which there is nothing more to say—but it should be further studied.

Note.—The structure of the base of this fungus in its young state before it protrudes the gelatinous ligule, accidentally omitted in its proper

place, is as follows. The texture of the base at that time inside is like the flesh of a ripe apple—if cut into slices with a knife—the color is greenish white as in a green apple; oozy-cellular, apparently radiating from the stalk. The green color soon changes to tawny orange—and then may be seen a few white branching fibers radiating from the stalk. As soon as the ligules are protruded on account of rainy weather, the base grows no more; but if the weather is not rainy the base enlarges day by day. The epidermis of the younger sporidochia, before their full maturity, has a somewhat filamentous-scaly texture, and the thickness of the skin of an apple. In their mature condition the ligules are covered with sporidia, just as in *P. Juniperi*—but the ligules are usually longer and not conic, often subflexuous and more attenuate toward the apex.

The asterisk was probably omitted from this number by mistake. Schweinitz evidently had many doubts about the true nature of this fungus and its generic position. In the North Carolina list he did not add “Sz.” to the name, nor did he supply a technical diagnosis, as in the case of his other new species. This may have been an accidental omission while in editorial hands, but is more likely an indication that Schweinitz hesitated regarding the best procedure.

(504. 1. [*Gymnosporangium*] *Juniperi* *Virginianæ*.)

N. B. Wholly to be separated, I believe, from the genus *Puccinia*, and to constitute with *Podisoma Juniperi*, on the European *Sabina*, a new genus, even of this order? (that *Podisoma Juniperi* should be reunited with *Gymnosporangium Juniperi*, Nees himself affirms). In both the form and substance of the gelatinous ligule, loaded with spores, it agrees with the European fungus mentioned; but ours has a remarkable base, a thing never seen in the European. This base, as I have termed it, a somewhat corky-fleshy body, is quite like the flesh of *Boletus hepaticus*, even in color, and is borne on an obconic stalk, attached by its tip to the slender branches of our cedars (*Juniperus Virginiana*) at the very top of the trees;—from this it changes into a hard (almost woody) capitulum, expanded, with incurved margins, marked with many pits, from which in wet weather are protruded the ligules, which when they have been dropped leave the pits empty. The color of the base is flesh-gray, of the fungus when fruiting and extruding the ligules strongly greenish golden, attracting the eye from a distance. Also, the capitulum is pendulous, and has a diameter of two to four inches.

Spores covering the external surface of the ligules, linear-oblong, somewhat curved, two-celled, when again wet after drying yellowish, exactly like Nees's illustration characterizing *Gymnosporangium*.)

Represented only by a mounted specimen, consisting of three galls, each about 1.5 cm. broad, one of which bears numerous projecting telia, 5 mm. long, the other two much eaten by insects. The fungus is one of the best known American rusts, now generally listed under the name first given by Schweinitz. Why Link changed the name, having no information except that supplied in Schweinitz's Carolina list, and not having seen a specimen, is not evident. Schweinitz accepts Link's substitute name, but places the species under the genus *Podisoma* for reasons which he states.

Note.—The above account includes all numbers pertaining to rusts in Schweinitz's "Synopsis Fungorum in America Boreali." It also includes all numbers possibly relating to rusts, given under *Æcidium*, *Uredo*, *Puccinia* and *Gymnosporangium* in his "Synopsis Fungorum Carolinæ Superioris" except two.

No. "460. [*Uredo*] *confluens* β ., rare on softer leaves, e. g. *Veratrum album*," is represented by no specimen or original packet at Philadelphia, and the identity of the collection must be left undecided. No rust is known that would answer the requirement.

No. "475. [*Uredo*] *Betæ*, α and β , here and there on leaves of the garden beet and on *Ipomæa pandurana*," is represented by no specimen or original packet. The most probable suggestion points to species of the Phycomycetous genus *Albugo* to account for this number.

SCHWEINITZ'S UREDINALES IN SYSTEMATIC ARRANGEMENT.

COLEOSPORIACEÆ.

COLEOSPORIUM IPOMÆÆ (Schw.) Burr. (*Uredo Ipomææ* Schw.,
Cæoma Ipomææ Link).

On *Ipomæa pandurata* L., II, III, North Carolina, 2824.

COLEOSPORIUM ELEPHANTOPODIS (Schw.) Thüm. (*Uredo Elephantopodis* Schw.,
Cæoma Elephantopodis Link).

On *Elephantopus tomentosus* L., II, North Carolina, 2825.

(COLEOSPORIUM VERNONIÆ Berk. & Curt.

On *Vernonia noveboracensis* (L.) Willd., North Carolina,
2826.)

COLEOSPORIUM SOLIDAGINIS (Schw.) Thüm. (*Uredo Solidaginis* Schw., *Cæoma Solidaginis* Schw.).

On *Solidago altissima* L., II, North Carolina, 2826.

Solidago rugosa Mill., II, Pennsylvania, 2826.

Solidago sempervirens L., II, New York, 2826.

Solidago serotina Ait., II, Pennsylvania, 2826.

COLEOSPORIUM TEREBINTHINACEÆ (Schw.) Arth. (*Uredo Terebinthinaceæ* Schw., *Cæoma Terebinthinaceæ* Schw.).

On *Silphium terebinthinaceum* Jacq., 2827.

COLEOSPORIUM HELIANTHI (Schw.) Arth. (*Cæoma Helianthi* Schw.).

On *Helianthus giganteus* L., ii, III, Pennsylvania, 2828.

UREDINACEÆ (*Melampsoraceæ*).

MELAMPSORA MEDUSÆ Thüm.

On *Populus dilatata* Ait. (*P. italica* Moench), II, Pennsylvania, 2855.

MELAMPSORA BIGELOWII Thüm.

On *Salix nigra* Marsh., II, Pennsylvania, 2856.

PUCCINIASTRUM AGRIMONIÆ (Schw.) Tranz. (*Cæoma Agrimonie* Schw.).

On *Agrimonia parviflora* Soland., II, North Carolina (Pennsylvania), 2835.

PUCCINIASTRUM MYRTILLI (Schum.) Arth. (*P. minimum* Arth., *Uredo minima* Schw., *Cæoma Azaleæ* Schw.).

On *Azalea nudiflora* L., II, North Carolina, Pennsylvania, 2838.

KUEHNEOLA UREDINIS (LINK) Arth. (*Phragmidium albidum* Lagerh.).

On *Rubus idæus* L., II, Pennsylvania, 2833.

MELAMPSOROPSIS PYROLÆ (DC.) Arth. (*Cæoma pyrolatum* Schw.,
Æcidium pyrolatum Schw., *Chrysomyxa Pyrolæ* Rostr.).

On *Pyrola uliginosa* Torr. (*P. rotundifolia* Am. Auct.), II,
New York, 2893.

HYALOPSORA ASPIDIOTUS (Peck) Magn.

On *Phegopteris Dryopteris* (L.) Fee (*Aspidium obtusum*
Muhl.), II, New York, 2836.

CRONARTIUM QUERCUS (Brond.) Schröt. (*Peridermium Cerebrum*
Peck).

On *Pinus virginicus* Mill. (*P. inops* Sol.), I, Pennsylvania,
2903.

PERIDERMIIUM INTERMEDIUM Arth. & Kern.

On *Pinus* sp., I, North Carolina, 2903.

ÆCIDIACEÆ (*Pucciniaceæ*).

RAVENELIA EPIPHYLLA (Schw.) Diet. (*Sphæria epiphylla* Schw.).

On *Cracca virginiana* L. (*Tephrosia virginiana* Pers., *Galega*
virginiana L.), III, North Carolina, 1474.

TRANZSCHELIA PUNCTATA (Pers.) Arth. (*Cæoma hepaticatum*
Schw., *Æcidium hepaticatum* Schw., *Puccinia Pruni-*
spinosa Pers.).

On *Hepatica Hepatica* (L.) Karst. (*H. triloba* Chaix., *Anem-*
one Hepatica L.), I, Pennsylvania, 2878.

POLYTHELIS FUSCA (Pers.) Arth. (*Puccinia Anemones* Pers.).

On *Anemone quinquefolia* L., III, Pennsylvania, 2936.

POLYTHELIS THALICTRI (Chev.) Arth. (*Cæoma Thalictri* Schw.,
Puccinia Thalictri Chev.).

On *Thalictrum polygamum* Muhl. (*T. Cornuti* Auct.), III,
New York, 2849.

?PHRAGMIDIUM IMITANS Arth.

On *Rubus idæus* L., I, Pennsylvania, 2854.

EARLEA SPECIOSA (Fries) Arth. (*Seiridium marginatum* Schw. not Nees, *S. Smilacis* Schw., *Phragmidium speciosum* Cooke).

On *Rosa carolina* L. (*R. corymbosa* Ehrh., *R. pauciflora* Muhl.), I, North Carolina, 2832; III, Pennsylvania, 3084.

Rosa virginiana Mill., III, Pennsylvania, 3085.

FROMMEA OBTUSA (Strauss) Arth. (*Puccinia Potentillæ* Schw., *Phragmidium Potentillæ-canadensis* Diet., *Kuehneola obtusa* Arth.).

On *Potentilla canadensis* II₁, II₂, North Carolina, Pennsylvania, 2834; III, Pennsylvania, 2945.

KUNKELIA NITENS (Schw.) Arth. (*Æcidium nitens* Schw., *A. luminatum* Schw., *Cæoma luminatum* Link).

On *Rubus Enslenii* Tratt., III, North Carolina, 2887.
Rubus sp., III, Pennsylvania, 2887.

GYMNOSPORANGIUM MYRICATUM (Schw.) Fromme (*G. Ellisii* Farl., *Cæoma myricatum* Schw., *Æcidium myricatum* Schw.).

On *Myrica cerifera* L., I, New York, 2894.

GYMNOSPORANGIUM JUNIPERI-VIRGINIANÆ Schw. (*G. macropus* Link, *Podisoma macropus* Schw., *Cæoma pyratum* Schw., *Æcidium pyratum* Schw.).

On *Malus coronaria* (L.) Mill. (*Pyrus coronaria* L., *P. angustifolia* Ait.), I, Pennsylvania, 2896.

Malus Malus (L.) Britton (*Pyrus Malus* L.), I, Pennsylvania, 2899δ, 2900.

Juniperus virginiana L., III, North Carolina, Pennsylvania, 3096.

GYMNOSPORANGIUM GLOBOSUM Farl.

On *Crataegus punctata* Jacq., I, Pennsylvania, 2899 α.

Pyrus communis L., I, North Carolina or Pennsylvania, or both, 2900.

GYMNOSPORANGIUM HYALINUM (Cooke) Kern (*Ræstelia hyalina* Cooke).

On *Cratægus viridis* L. (*C. arborescens* Ell.), I, North Carolina, 2899β.

GYMNOSPORANGIUM TRACHYSORUM Kern.

On *Cratægus Oxyacantha* L., I, Pennsylvania, 2899γ.

GYMNOSPORANGIUM BOTRYAPITES (Schw.) Kern (*G. biseptatum* Ellis, *Cæoma botryapites* Schw., *Ceratites botryapites* Schw.).

On *Amelanchier canadensis* (L.) Medic. (*Aronia Botryapium* Pers.), I, Pennsylvania, 2902.

GYMNOSPORANGIUM GERMINALE (Schw.) Kern (*G. clavipes* C. & P., *Cæoma germinale* Schw., *Peridermium germinale* Schw.).

On *Cratægus* sp., I, Pennsylvania, 2904.

Juniperus virginiana L., III, Pennsylvania, 3094.

GYMNOSPORANGIUM CLAVARIÆFORME (Jacq.) DC.

On *Juniperus communis* L., III, Pennsylvania, 3095.

UROMYCES JUNCI-EFFUSI Syd. (*Puccinia Junci* Schw.).

On *Juncus effusus* L., II, III, Pennsylvania, 2906, 2913.

UROMYCES CALADII (Schw.) Farl. (*Æcidium Caladii* Schw., *A. aroidatum* Link, *A. dracontionatum* Schw., *Uredo Caladii* Schw., *Cæoma Caladii* Schw., *C. aroidatum* Link, *C. Arivirginici* Schw., *C. dracontionatum* Schw., *Puccinia Aritriphylli* Schw.).

On *Arisæma triphyllum* (L.) Schott (*Arum triphyllum* L.), III, Pennsylvania, 2946.

Muricauda Dracontium (L.) Small (*Arum Dracontium* L., *Arisæma Dracontium* Schott), I, North Carolina, Pennsylvania, 2861.

Peltandra virginica (L.) Kunth (*Arum virginicum* L.), II,

North Carolina, Pennsylvania, 2839; I, North Carolina, 2860.

UROMYCES HOUSTONIATUS (Schw.) Sheldon (*Cæoma houstoniatum* Schw., *Æcidium houstoniatum* Schw.).

On *Houstonia carulea* L., I, Pennsylvania, 2891.

UROMYCES HYPERICI-FRONDOSI (Schw.) Arth. (*Æcidium Hypericifrondosi* Schw., *A. hypericatum* Schw., *Cæoma Hyperici* Schw., *C. hypericatum* Link).

On *Hypericum prolificum* L. (*H. frondosum* Michx.), I, North Carolina, 2883.

Hypericum sp., II, North Carolina, 2842; I, Pennsylvania, 2883.

UROMYCES PEDATATUS (Schw.) Sheldon (*U. Andropogonis* Tracy, *Æcidium pedatatum* Schw., *A. sagittatum* Schw., *Cæoma pedatatum* Schw., *C. sagittatum* Schw.).

On *Viola pedata* L., I, Pennsylvania, 2885.

Viola primulæfolia L., I, Pennsylvania, 2884 p.p.

Viola sagittata Ait., I, Pennsylvania, 2886.

UROMYCES APPENDICULATUS (Pers.) Fries (*Uredo appendiculata* Pers., *Puccinia Phaseoli-trilobi* Schw.).

On *Phaseolus vulgaris* L., II, North Carolina, Pennsylvania, 2845.

Strophostyles helvolva (L.) Britton (*Phaseolus trilobus* Michx.), III, New York, 2942.

UROMYCES FABÆ (Pers.) DeBary (*Uredo Viciæ* Pers., *Cæoma leguminosarum* Schlecht., *Puccinia Fabæ* Link.).

On *Vicia Faba* L., II, III, North Carolina, Pennsylvania, 2847, 2943.

UROMYCES LESPEDEZÆ-PROCUMBENTIS (Schw.) M. A. Curt. (*Puccinia Lespedezæ-procumbentis* Schw., *P. Lespedezæ-polytachyæ* Schw., *P. Lespedezæ-violaceæ* Schw.).

On *Lespedeza hirta* (L.) Hornem. (*L. polystachya* Michx.), III, North Carolina, 2941.

Lespedeza procumbens Michx., III, North Carolina, Pennsylvania, 2940.

Lespedeza violacea (L.) Pers., III, North Carolina, New Jersey, 2941.

UROMYCES HEDYSARI-PANICULATI (Schw.) Farl. (*Puccinia Hedysari-paniculati* Schw., *Phragmidium Hedysari* Schw.).

On *Meibomia paniculata* (L.) Kuntze (*Hedysarum paniculatum* L., *Desmodium paniculatum* DC.), III, North Carolina, Pennsylvania, 2947.

UROMYCES PROËMINENS (DC.) Pass. (*Æcidium Euphorbiæ-hypericifoliæ* Schw., *Cæoma Euphorbiæ-hypericifoliæ* Schw.).

On *Chamæsyce maculata* (L.) Small (*Euphorbia maculata* L.), I, North Carolina, 2846.

Chamæsyce Preslii (Guss.) Arth. (*Euphorbia Preslii* Guss.), II, III, North Carolina, Pennsylvania, 2846; I, North Carolina, Pennsylvania, 2890.

UROMYCES SPERMACOCES (Schw.) M. A. Curt. (*Cæoma Spermacoces* Schw., *Puccinia Spermacoces* Schw.).

On *Diodia teres* Walt. (*Spermacoce diodina* Michx.), ii, III, North Carolina, Pennsylvania, 2840.

PUCCINIA POCULIFORMIS (Jacq.) Wettst. (*Æcidium Berberidis* Pers., *Cæoma berberidatum* Link, *Puccinia graminis* Pers.).

On *Berberis vulgaris* L., I, North Carolina, 2881.

Triticum vulgare Vill., II, New York, 2817; III, Pennsylvania, 2905.

PUCCINIA EPIPHYLLA (L.) Wettst. (*P. Poarum* Niessl).

On *Poa pratensis* L., II, North Carolina, 2818.

PUCCINIA VIRGATA Ellis & Ev. (*Cæoma Andropogi* Schw.).

On *Sorghastrum nutans* (L.) Nash (*Andropogon avenaceum* Michx.), II, iii, Pennsylvania, 2820.

PUCCINIA MAJANTHÆ (Schum.) Arth. (*Æcidium Uvulariæ* Schw., *Æcidium uvulariatum* Schw., *Cæoma convallariatum* Link, *C. uvulariatum* Schw.).

On *Uvularia perfoliata* L., I, North Carolina, 2858.

Vagnera racemosa (L.) Morong (*Smilacina racemosa* Desf.), I, Pennsylvania, 2857.

PUCCINIA ANDROPOGONIS Schw. (*P. Zizaniæ* Schw., *Æcidium Pentstemonis* Schw., *A. pentstemoniatum* Schw., *Cæoma pentstemoniatum* Schw.).

On *Andropogon scoparius* Michx., III, Pennsylvania, 2911.

Andropogon virginicus L., III, Pennsylvania, 2915.

Pentstemon australis Small, I, North Carolina, 2864.

PUCCINIA FRAXINATA (Link) Arth. (*Æcidium Fraxini* Schw., *Cæoma fraxinatum* Link, *C. fraxinites* Schw.).

On *Fraxinus* sp., I, North Carolina, Pennsylvania, 2901.

PUCCINIA ARUNDINARIÆ Schw.

On *Arundinaria* sp., III, Carolina, 2907.

PUCCINIA CLEMATIDIS (DC.) Lagerh. (*P. Agropyri* Ellis & Ev., *Æcidium Clematidis* Schw., *A. clematitatum* Schw., *Cæoma clematitatum* Schw.).

On *Clematis virginiana* L., I, North Carolina, Pennsylvania, 2874.

PUCCINIA EATONIÆ Arth. (*Æcidium Ranunculi* Schw.).

On *Ranunculus abortivus* L., I, North Carolina, Pennsylvania, 2875.

PUCCINIA HIBISCIATA (Schw.) Kellerm. (*P. Muhlenbergiæ* Arth. & Holw., *Æcidium hibisciatum* Schw., *Cæoma hibisciatum* Schw.).

On *Hibiscus militaris* Cav., I, Pennsylvania, 2877.

PUCCINIA IMPATIENTIS (Schw.) Arth. (*P. perminuta* Arth., *Æcidium Impatientis* Schw., *A. impatientatum* Schw., *Cæoma impatientatum* Schw.).

On *Impatiens biflora* Walt. (*I. maculata* Muhl.), I, North Carolina, Pennsylvania, 2880.

PUCCINIA SORGHII Schw.

On *Zea Mays* L., ii, III, Pennsylvania, 2910.

PUCCINIA EMACULATA Schw.

On *Panicum capillare* L., III, Pennsylvania, 2912.

PUCCINIA WINDSORIÆ Schw.

On *Tridens flavus* (L.) Hitchc. (*Poa quinquifida* Pursh, *P. seslerioides* Michx., *P. flava* L.), III, Pennsylvania, 2914.

PUCCINIA LYSIMACHIATA (Link) Kern (*P. limosa* Magn., *Æcidium Lysimachiae* Schw., *Cæoma lysimachiatum* Link).

On *Lysimachia quadrifolia* L., I, North Carolina, 2863.

Lysimachia terrestris (L.) B. S. P. (*L. racemosa* Lam., *L. stricta* Ait.), I, North Carolina, Pennsylvania, 2863.

PUCCINIA HIERACIATA (Schw.) Arth. & Bisby (*P. patruelis* Arth., *Æcidium hieraciatum* Schw., *Cæoma hieraciatum* Schw.)

On *Hieracium paniculatum* L., I, Pennsylvania, 2868.

PUCCINIA ASTERUM (Schw.) Kern (*P. extensicola* Plowr., *Æcidium Asterum* Schw., *A. asteratum* Schw., *A. erigeronatum* Schw., *A. Solidaginis* Schw., *Cæoma asteratum* Link, *C. erigeronatum* Schw.).

On *Aster paniculatus* Lam., I, North Carolina, 2870.

Erigeron annuus Pers. (*E. heterophyllus* Muhl.), I, Pennsylvania, 2869.

Solidago sp., I, North Carolina, 2870.

PUCCINIA IRIDIS (DC.) Wallr. (*Cæoma Iridis* Schw.).

On *Iris versicolor* L., II, Pennsylvania, 2812

PUCCINIA POLYGONI-AMPHIBII Pers. (*P. polygonorum* Link, *P. Polygoni-pensilvanici* Schw., *P. concentrica* Schw., *Æcidium Geranii-maculati* Schw.).

On *Geranium maculatum* L., I, North Carolina, 2879.

Persicaria emersa (Michx.) Small (*Polygonum coccineum* Muhl.), II, III, Pennsylvania, 2918.

Persicaria pennsylvanica (L.) Small (*Polygonum pennsylvanicum* L.), III, North Carolina, 2917.

Tovara virginiana (L.) Raf. (*Polygonum virginianum* L.), III, Pennsylvania, 2917, 2918.

PUCCINIA CLAYTONIATA (Schw.) Peck (*Æcidium claytoniatum* Schw., *Cæoma claytoniatum* Schw.).

On *Claytonia virginica* L., I, New York, 2892.

PUCCINIA ANEMONES-VIRGINIANÆ Schw. (*P. solida* Schw.):

On *Anemone virginiana* L., III, North Carolina, Pennsylvania, 2937.

PUCCINIA PODOPHYLLI Schw. (*P. aculeata* Link, *Æcidium Podophylli* Schw., *A. podophyllatum* Schw.).

On *Podophyllum peltatum* L., I, III, North Carolina, Pennsylvania, 2888, 2939.

PUCCINIA HEUCHERÆ (Schw.) Dietel (*Cæoma Heucherae* Link, *Uredo Heucherae* Schw.).

On *Heuchera americana* L., III, North Carolina, 2843.

Heuchera villosa Michx., III, North Carolina, 2843.

PUCCINIA VIOLÆ (Schum.) DC. (*Æcidium Violæ* Schum., *Cæoma violatum* Link).

On *Viola hastata* Michx., I, North Carolina, 2884 p.p.

PUCCINIA SAMBUCI (Schw.) Arth. (*P. Bolleyana* Sacc., *Æcidium Sambuci* Schw., *A. sambuciatum* Schw., *Cæoma sambuciatum* Schw.).

On *Sambucus canadensis* L., I, North Carolina, Pennsylvania, 2897.

PUCCINIA GROSSULARIÆ (Schum.) Lagerh. (*Cæoma grossulariatum* Link).

On *Carex* sp., III, Pennsylvania, 2908 p.p.

Grossularia oxycanthoides (L.) Mill. (*Ribes oxycanthoides* L.), I, Pennsylvania, 2882.

PUCCINIA ELEOCHARIDIS Arth. (*Cæoma compositarum* Link p.p.).

On *Eupatorium purpureum* L., I, Pennsylvania, 2867 β.

PUCCINIA ANGUSTATA Peck.

On *Scirpus cyperinus* (L.) Kunth, III, Pennsylvania, 2908 p.p., 2909.

PUCCINIA CANALICULATA (Schw.) Lagerh. (*Sphæria canaliculata* Schw.).

On *Cyperus* sp., III, Pennsylvania, 1487.

PUCCINIA SMILACIS Schw. (*Æcidium Smilacis* Schw., *A. smilacinatum* Schw., *Cæoma smilacinatum* Link, *Uredo Smilacis* Schw.).

On *Smilax rotundifolia* L., I, North Carolina, 2859; II, same, 2822; III, same, 2916.

Smilax sp., II, Pennsylvania, 2822; III, same, 2916.—

PUCCINIA CIRCÆÆ Pers.

On *Circæa Lutetiana* L., III, North Carolina, Pennsylvania, 2831, 2938.

PUCCINIA PIMPINELLÆ (Strauss) Mart. (*P. Myrrhis* Schw., *P. Osmorrhizæ* C. & P., *Cæoma Anemonis* Schw., *C. Chærophylli* Schw.).

On *Chærophyllum procumbens* (L.) Crantz (*Myrrhis procumbens* Spreng.), II, III, Pennsylvania, 2934.

Osmorrhiza Claytoni (Michx.) Clarke (*Myrrhis Claytoni* Michx.), II, III, Pennsylvania, 2841.

Osmorrhiza sp. (not *Anemone* or *Chelidonium*), II., Pennsylvania, 2829; II, III, New York, 2851.

PUCCINIA MENTHÆ Pers. (*P. Pycnanthemis* Schw., *Cæoma labiatarum* Link, *Uredo Clinopodii* Schw.).

On *Koellia incana* (L.) Kuntze (*Clinopodium incanum* L., *Pycnanthemum incanum* Michx.), II, North Carolina, Pennsylvania, 2823; III, Pennsylvania, 2920.

PUCCINIA VERRUCOSA (Schultz) Link (*P. Hyssopi* Schw.).

On *Agastache scrophulariæfolia* (Willd.) Kuntze (*Hyssopus scrophulariæfolius* Willd.) III, Pennsylvania, 2944.

PUCCINIA MACULOSA Schw. not Strauss (?*Æcidium Dandelionis* Schw.).

On (?) *Adopogon Dandelion* (L.) Kuntze (*Krigia Dandelion* Nutt., *Tragopogon Dandelion* L., *Cynthia Dandelion* DC.), III, North Carolina, 2867 a.

Adopogon virginicus (L.) Kuntze (*Krigia virginica* Willd., *Cynthia virginica* D. Don), III, Pennsylvania, 2922.

PUCCINIA XANTHII Schw.

On *Xanthium* sp., III, North Carolina, Pennsylvania, 2927.

PUCCINIA VERNONIÆ Schw. (*P. bullata* Schw. not Link, *P. longipes* Lagerh.).

On *Vernonia noveboracensis* (L.) Willd., III, Pennsylvania, 2919.

Vernonia sp., III, North Carolina, 2919; III, Pennsylvania, 2926.

PUCCINIA KUHNIÆ Schw.

On *Kuhnia eupatorioides* L., III, Pennsylvania, 2931.

PUCCINIA TENUIS (Schw.) Burr. (*Æcidium tenue* Schw., *Cæoma tenue* Schw.).

On *Eupatorium ageratoides* L.f., I, Pennsylvania, 2889.

PUCCINIA HELIOPSISIDIS Schw.

On *Heliopsis* sp., III, North Carolina, Pennsylvania, 2924.

PUCCINIA HELIANTHI-MOLLIS (Schw.) Arth. & Bisby (*P. Helianthi* Schw., *P. Helianthorum* Schw., *Æcidium Helianthi-mollis* Schw., *A. helianthatum* Schw., *A. trachelifoliatum* Schw., *Cæoma helianthatum* Schw., *C. trachelifoliatum* Schw.).

On *Helianthus mollis* Lam., I, North Carolina, Pennsylvania, 2871.

Helianthus tracheliifolius Willd., I, Pennsylvania, 2872.

Helianthus tuberosus L., III, Pennsylvania, 2923.

Helianthus sp., III, North Carolina, Pennsylvania, 2923.

PUCCINIA VERBESINÆ Schw. (*Æcidium Verbesinæ* Schw.).

On *Verbesina [occidentalis* (L.) Walt.], I, North Carolina, 2870; III, same, 2925.

PUCCINIA GNAPHALIATA (Schw.) Arth. & Bisby (*P. investita* Schw., *Æcidium gnaphaliatum* Schw., *Cæoma gnaphaliatum* Schw.).

On *Gnaphalium obtusifolium* L. (*G. polycephalum* Michx.), I, Pennsylvania, 2873; III, same, 2932.

PUCCINIA CIRSII Lasch (*P. compositarum* Link, p.p.).

On *Cirsium altissimum* (L.) Spreng. (*Cnicus altissimus* Willd.), III, Pennsylvania, 2921.

PUCCINIA ASTERIS Duby (*P. Asteris* Schw., *P. Helenii* Schw.).

On *Aster cordifolius* L., III, Pennsylvania, 2930.

Aster paniculatus Lam., III, Pennsylvania, 2930.

Aster salicifolius Lam. III, Pennsylvania, 2928.

PUCCINIA SILPHII Schw.

On *Silphium trifoliatum* L.; III, North Carolina, 2929.

ÆCIDIUM APOCYNII Schw. (*A. apocynatum* Schw., *Cæoma apocynatum* Schw.).

On *Apocynum cannabinum* L., I, North Carolina, 2865.

ÆCIDIUM CIMICIFUGATUM Schw. (*Cæoma cimicifugatum* Schw.).

On *Cimicifuga racemosa* (L.) Nutt., I, Pennsylvania, 2876.

EXCLUDED NAMES.

The following names and numbers apply to forms that are not rusts, or if so are impossible of identification.

Cæoma (Uredo) rimosum Link.

On *Scirpus lacustris* L. (*S. acutus* Muhl.), New York, 2819;
no fungus present, probably mechanical injury.

Cæoma (Uredo) Campanularum Link (*Uredo Campanulæ* Schw.).

On *Specularia perfoliata* (L.) A. DC. (*Campanula perfoliata* L., *C. amplexicaulis* Michx.), North Carolina, Pennsylvania, 2830; no specimen preserved, probably not a rust.

Cæoma (Uredo) Teucrui Schw.

On *Teucrium canadense* L. (*T. virginicum* L.), Pennsylvania, 2837; a Hyphomycetous fungus, *Cercospora Teucrui* (Schw.) Arth. & Bisby (*C. racemosa* E. & M.).

Cæoma (Uredo) apiculosum Link (*Uredo flosculosorum* Alb. & Schw.).

On various hosts, North Carolina, Pennsylvania, 2844; no specimen preserved, and the name so loosely applied as to have no value.

Cæoma (Uredo) Lobeliæ-cardinalis Schw.

On *Lobelia cardinalis* L., Pennsylvania, 2848; a Hyphomycetous fungus, usually called *Cercospora effusa* (B. & C.) Ellis & Ev.

Cæoma (Uredo) brunneum Schw.

On an undetermined leguminous plant, Pennsylvania, 2850; some pathological condition, but no fungus present.

Cæoma (*Æcidium*) *rubellatum* Link (*Æcidium Rumicis* Schw.).

On *Rumex* "and *Grossularia*," North Carolina, Pennsylvania, 2862; no specimen preserved, probably young fungi imperfecti, certainly not a rust.

Cæoma (*Æcidium*) *convolvulatum* Schw. (*Æcidium Ipomææ-panduranæ* Schw., *A. convolvulatum* Schw.).

On *Ipomæa pandurata* L., North Carolina, Pennsylvania, 2866; not a rust, but one of the *Peronosporales*, *Albugo Ipomææ-panduranæ* (Schw.) Swingle.

Cæoma (*Æcidium*) *osmundatum* Schw. (*Æcidium osmundatum* Schw.).

On *Osmunda spectabilis* Willd., New York, 2895; not a rust, but a fungus of uncertain affinity, *Mycosyrinx Osmundæ* Peck (*Ustilago Osmundæ* Peck).

Cæoma (*Æcidium*) *urticatum* Link (*Æcidium Asperifolii* Schw.).

On *Cynoglossum virginicum* L. (*C. amplexicaule* Muhl.) and *Urtica* sp., North Carolina, 2898; no specimen preserved, — very doubtful, but certainly not a rust.

Puccinia Bullaria Schw. not Link.

On *Agastache nepetoides* (L.) Kuntze (*Lophanthus nepetoides* Benth., *Hyssopus nepetoides* L.), Pennsylvania, 2935; no specimen in Philadelphia, but one in Washington, not a rust, may be an ascomycete.

CHRONOLOGICAL ENUMERATION.

After the serial numbers the corresponding numbers from the Carolina list, when there are any, are given in parentheses. The Schweinitz name is followed by the name at present in use, or other identification. An original specimen at the Philadelphia Academy of Sciences is indicated when in an autographic packet by an asterisk *, when mounted by a dagger †.

- *†1474 (130) *Sphaeria epiphylla* L.v.S. = *Ravenelia epiphylla* (Schw.) Diet.
- *†1487 - " *canaliculata* L.v.S. = *Puccinia canaliculata* (Schw.) Lagerh.
- *†2817 - *Cæoma (Uredo) Rubigo* Lk. = *Puccinia poculiformis* (Jacq.) Wettst.
- †2818 (464) " " *linearis* Lk. = *Puccinia epiphylla* (L.) Wettst.
- *†2819 - " " *rimosum* Lk. = no fungus, mechanical injury.
- *†2820 - " " *Andropogi* L.v.S. = *Puccinia virgata* Ell. & Ev.
- *†2821 - " " *Iridis* L.v.S. = *Puccinia Iridis* (DC.) Wallr.
- †2822 (471) " " *Smilacis* L.v.S. = *Puccinia Smilacis* Schw.
- 2823 (469) " " *Labiatarum* Lk. = *Puccinia Menthæ* Pers.
- *†2824 (468) " " *Ipomææ* L.v.S. = *Coleosporium Ipomææ* (Schw.) Burr.
- *†2825 (467) " " *Elephantopodis* L.v.S. = *Coleosporium Elephantopodis* (Schw.) Thüm.
- *†2826 (472) " " *Solidaginis* L.v.S. = *Coleosporium Solidaginis* (Schw.) Thüm.
- 2827 (473) " " *Terebinthinaceæ* L.v.S. = *Coleosporium Terebinthinaceæ* (Schw.) Arth.
- *†2828 - " " *Helianthi* L.v.S. = *Coleosporium Helianthi* (Schw.) Arth.
- †2829 - " " *Anemonis* L.v.S. = *Puccinia Pimpinellæ* (Str.) Mart.
- 2830 (465) " " *Campanularum* Lk. = uncertain, probably not a rust.
- 2831 (466) " " *Onagræarum* Lk. = *Puccinia Circææ* Pers.
- *†2832 (463) " " *miniata* Lk. = *Earlea speciosa* (Fries) Arth.
- *2833 - " " *ruborum* Lk. = *Kuehneola Uredinis* (Link) Arth.
- †2834 (461) " " *Potentillarum* Lk. = *Frommea obtusa* (Str.) Arth.
- *†2835 (462) " " *Agrimoniæ* L.v.S. = *Pucciniastrum Agrimoniæ* (Schw.) Tranz.
- *†2836 - " " *Filicum* Lk. = *Hyalospora Aspidiotus* (Peck) Magn.
- †2837 - " " *Teucrii* L.v.S. = *Cercospora Teucrii* (Schw.) Arth. & Bisby, not a rust.
- †2838 (470) " " *Azaleæ* L.v.S. = *Pucciniastrum Myrtilli* (Schum.) Arth.
- †2839 (480) " " *Ari virginici* L.v.S. = *Uromyces Caladii* (Schw.) Farl.
- †2840 (502) " " *Spermacoces* L.v.S. = *Uromyces Spermacoces* (Schw.) M. A. Curt.
- †2841 - " " *Chærophylli* L.v.S. = *Puccinia Pimpinellæ* (Str.) Mart.
- †2842 - " " *Hyperici* L.v.S. = *Uromyces Hyperici-frondosi* (Schw.) Arth.
- †2843 (479) " " *Heucherae* L.v.S. = *Puccinia Heucherae* (Schw.) Diet.

- 2844 (478) *Cæoma* (*Uredo*) *apiculosum* Lk. = uncertain, name of no value.
- *†2845 (477,490) " " *appendiculosum* = *Uromyces appendiculatus*
Lk. (Pers.) Fries.
- *†2846 (459,474) " " *punctuosum* Lk. = *Uromyces proëminens* (DC.)
Pass.
- 2847 (476) " " *Leguminosarum* = *Uromyces Fabæ* (Pers.) De-
Lk. Bary.
- †2848 - " " *Lobeliæ cardi-* = *Cercospora effusa* (B. & C.)
nalis L.v.S. Ell. & Ev., not a rust.
- †2849 - " " *Thalictri* L.v.S. = *Polythelis Thalictri* (Chev.)
Arth.
- †2850 - " " *brunneum* L.v.S. = uncertain, not a fungus.
- †2851 - " " *Chelidonii* L.v.S. = *Puccinia Pimpinellæ* (Str.)
Mart.
- 2854 - " " *gyrosum* Lk. = uncertain, may be *Phragmid-*
ium imitans Arth.
- *†2855 - " " *cylindricum* Lk. = *Melampsora Medusæ* Thüm.
- *†2856 - " " *epiteum* Lk. = *Melampsora Bigelowii* Thüm.
- †2857 - " " (*Æcidium*) *Convallaria-* = *Puccinia Majanthæ* (Schum.)
tum Lk. Arth. & Holw.
- †2858 (453) " " *Uvulariatum* = *Puccinia Majanthæ* (Schum.)
L.v.S. Arth. & Holw.
- †2859 (452) " " *Smilacinatum* = *Puccinia Smilacis* Schw.
L.v.S.
- †2860 (457) " " *Aroidatum* L.v.S. = *Uromyces Caladii* (Schw.)
Farl.
- *†2861 - " " *Dracontionatum* = *Uromyces Caladii* (Schw.)
L.v.S. Farl.
- 2862 (433) " " *rubellatum* Lk. = uncertain, not a rust.
- †2863 (438) " " *Lysimachiatum* = *Puccinia lysimachiata* (Link)
Lk. Kern.
- *2864 (449) " " *Pentstemonia-* = *Puccinia Andropogonis* Schw.
tum L.v.S.
- *†2865 (448) " " *Apocynatum* = *Æcidium apocynatum* Schw.
L.v.S.
- *†2866 (454) " " *Convolvulatum* = *Albugo Ipomææ-panduranæ*
L.v.S. (Schw.) Swingle, not a rust.
- *2867 (434) " " *Compositarum* { α = uncertain, may be *Puccinia*
maculosa Schw.
Lk. { β = *Puccinia Eleocharidis* Arth.
- †2868 - " " *Hieraciatum* = *Puccinia hieraciata* (Schw.)
L.v.S. Arth. & Bisby.
- †2869 - " " *Erigeronatum* = *Puccinia Asterum* (Schw.)
L.v.S. Kern.
- { 2870 (444,446) " " *Asteratum* L.v.S. = *Puccinia Asterum* (Schw.)
Kern.
- { 2870 (445) " " *Asteratum* L.v.S. = *Puccinia Verbesinæ* Schw.

- †2871 (450) *Cæoma* (*Æcidium*) *Helian-* = *Puccinia Helianthi-mollis*
thatum L.v.S. (Schw.) Arth. & Bisby.
- *†2872 - " " *Trachelifoliatum* = *Puccinia Helianthi-mollis*
L.v.S. (Schw.) Arth. & Bisby.
- *†2873 - " " *Gnaphaliatum* = *Puccinia gnaphaliata* (Schw.)
L.v.S. Arth. & Bisby.
- 2874 (447) " " *Clematitatum* = *Puccinia Clematidis* (DC.)
L.v.S. Lagerh.
- †2875 (440) " " *Ranunculaceatum* = *Puccinia Eatoniae* Arth.
Lk.
- †2876 - " " *Cimicifugatum* = *Æcidium cimicifugatum* Schw.
L.v.S.
- †2877 - " " *Hibisciatum* = *Puccinia hibisciata* (Schw.)
L.v.S. Kellerm.
- 2878 - " " *Hepaticatum* = *Tranzschelia punctata* (Pers.)
L.v.S. Arth.
- †2879 (443) " " *Geraniatum* Lk. = *Puccinia Polygoni-amphibii*
Pers.
- †2880 (442) " " *Impatientatum* = *Puccinia Impatientis* (Schw.)
L.v.S. Arth.
- †2881 (437) " " *Berberidatum* = *Puccinia poculiformis* (Jacq.)
Lk. Wettst.
- †2882 - " " *grossulariatum* = *Puccinia Grossulariae* (Schum.)
Lk. Lagerh.
- *†2883 (451) " " *Hypericatum* = *Uromyces Hyperici-frondosi*
L.v.S. (Schw.) Arth.
- †2884 (439) " " *Violatum* Lk. = $\begin{cases} \textit{Puccinia Violae} \text{ (Schum.) DC.} \\ \textit{Uromyces pedatatus} \text{ (Schw.)} \\ \text{Sheldon.} \end{cases}$
- *†2885 - " " *pedatatum* L.v.S. = *Uromyces pedatatus* (Schw.)
Sheldon.
- †2886 - " " *sagittatum* L.v.S. = *Uromyces pedatatus* (Schw.)
Sheldon.
- *†2887 (458) " " *luminatum* L.v.S. = *Kunkelia nitens* (Schw.) Arth.
- *†2888 (435) " " *Podophyllatum* = *Puccinia Podophylli* Schw.
L.v.S.
- †2889 - " " *tenue* L.v.S. = *Puccinia tenuis* (Schw.) Burr.
- †2890 [455] " " *Euphorbiæ-hyper-* = *Uromyces proëminens* (DC.)
icifoliae L.v.S. Pass.
- *†2891 - " " *Houstoniatum* = *Uromyces houstoniatus*
L.v.S. (Schw.) Sheldon.
- *†2892 - " " *Claytoniatum* = *Puccinia claytoniata* (Schw.)
L.v.S. Peck.
- †2893 - " " *Pyrolatum* L.v.S. = *Melampsoropsis Pyrolae* (DC.)
Arth.
- *†2894 - " " *myricatum* L.v.S. = *Gymnosporangium myricatum*
(Schw.) Fromme.
- †2895 - " " *Osmundatum* = *Mycosyrinx Osmundae* Peck,
L.v.S. not a rust.

- †2896 - *Cæoma* (*Æcidium*) *Pyratum* = *Gymnosporangium Juniperi-*
L.v.S. *virginianæ* Schw.
- *†2897 (441) " " *sambuciatum* = *Puccinia Sambuci* (Schw.)
L.v.S. Arth.
- 2898 (436) " " *Urticatum* Lk. = uncertain; not a rust.
- *†2899 (432) " (*Ræstelia*) *Cylindrites* = *Gymnosporangium globosum*
Lk. α Farl.
β = " *hyalinum* (Cooke) Kern.
γ = " *trachysorum* Kern.
δ = " *Juniperi-virginianæ* Schw.
- *†2900 (431) " " *Ræstelites* Lk. = { " *Juniperi-virginianæ* Schw.
" *globosum* Farl.
- †2901 (430) " " *Fraxinites* L.v.S. = *Puccinia fraxinata* (Link)
Arth.
- *†2902 - " " *Botryapites* = *Gymnosporangium botryapites*
L.v.S. (Schw.) Kern.
- †2903 (456) " (*Peridermium*) *Pineum* { *Cronartium Quercus* (Brond.)
Schröt.
Lk. = *Peridermium intermedium*
Arth. & Kern.
- †2904 - " " *germinale* L.v.S. = *Gymnosporangium germinale*
(Schw.) Kern.
- *2905 (492) *Puccinia graminis* Lk. = *Puccinia poculiformis* (Jacq.)
Wettst. in part.
- *2906 - " *striola* Lk. = *Uromyces Junci-effusi* Syd.
- *2907 (487) " *Arundinariæ* L.v.S. = *Puccinia Arundinariæ* Schw.
- *2908 - " *punctum* Lk. = { *Puccinia Grossulariæ*
(Schum.) Lagerh.
Puccinia angustata Peck.
- *2909 - " *Scirpi* Lk. = *Puccinia angustata* Peck.
- *2910 - " *Sorghi* L.v.S. = *Puccinia Sorghi* Schw.
- *2911 - " *Andropogi* L.v.S. = *Puccinia Andropogonis* Schw.
- *2912 - " *emaculata* L.v.S. = *Puccinia emaculata* Schw.
- *2913 - " *Junci* L.v.S. = *Uromyces Junci-effusi* Syd.
- *2914 - " *Windsoriæ* L.v.S. = *Puccinia Windsoriæ* Schw.
- *2915 - " *Zizaniæ* L.v.S. = *Puccinia Andropogonis* Schw.
- 2916 - " *Smilacis* L.v.S. = *Puccinia Smilacis* Schw.
- *2917 - " *Polygonorum* Lk. = *Puccinia Polygoni-amphibii*
Pers.
- *2918 - " *concentrica* L.v.S. = *Puccinia Polygoni-amphibii*
Pers.
- *2919 (501) " *bullata* L.v.S. = *Puccinia Vernoniæ* Schw.
- 2920 - " *Pycnanthemis* L.v.S. = *Puccinia Menthæ* Pers.
- *2921 - " *compositarum* Lk. = *Puccinia Cirsii* Lasch.
- 2922 - " *maculosa* [L.v.S. not] = *Puccinia maculosa* Schw.
Strauss
- 2923 (495) " *Helianthorum* L.v.S. = *Puccinia Helianthi-mollis*
(Schw.) Arth. & Bisby.

- 2924 (493) *Puccinia Heliopsidis* L.v.S. = *Puccinia Heliopsidis* Schw.
 2925 (496) " *Verbesinæ* L.v.S. = *Puccinia Verbesinæ* Schw.
 *2926 - " *Vernoniæ* L.v.S. = *Puccinia Vernoniæ* Schw.
 *2927 (500) " *Xanthii* L.v.S. = *Puccinia Xanthii* Schw.
 *2928 - " *Helenii* L.v.S. = *Puccinia Asteris* Duby.
 *2929 - " *Silphii* L.v.S. = *Puccinia Silphii* Schw.
 *2930 - " *Asteris* L.v.S. = *Puccinia Asteris* Duby.
 *2931 - " *Kuhnii* L.v.S. = *Puccinia Kuhnii* Schw.
 2932 - " *investita* L.v.S. = *Puccinia gnaphaliata* (Schw.)
 Arth. & Bisby.
 2933 (499) " *Galii* L.v.S. = *Puccinia punctata* Link.
 *2934 - " *Myrrhis* L.v.S. = *Puccinia Pimpinellæ* (Str.)
 Mart.
 2935 - " *Bullaria* [L.v.S. not] Lk. = uncertain; not a rust.
 2936 - " *anemones* Lk. = *Polythelis fusca* (Pers.) Arth.
 2937 (486) " *solida* L.v.S. = *Puccinia Anemones-virginianæ*
 Schw.
 *2938 (491) " *Circææ* Lk. = *Puccinia Circææ* Pers.
 2939 (489) " *aculeata* L.v.S. = *Puccinia Podophylli* Schw.
 2940 (497) " *Lespedezæ procumbentis* L.v.S. = *Uromyces Lespedezæ-procumbentis* (Schw.) M. A. Curt.
 2941 (498) " " *violaceæ* L.v.S. = *Uromyces Lespedezæ-procumbentis* (Schw.) M. A. Curt.
 2942 - " *Phaseoli trilobi* L.v.S. = *Uromyces appendiculatus*
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 2943 - " *Fabæ* Lk. = *Uromyces Fabæ* (Pers.) De-
 Bary.
 *2944 - " *Hyssopi* L.v.S. = *Puccinia verrucosa* (Schultz)
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 2945 - " *Potentillæ* L.v.S. = *Frommea obtusa* (Strauss)
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 *2946 - " *Ari triphylli* L.v.S. = *Uromyces Caladii* (Schw.)
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 2947 (503) *Phragmidium Hedysari* L.v.S. = *Uromyces Hedysari-paniculati*
 (Schw.) Farl.
 †3084 - *Seiridium marginatum* [L.v.S. not] Lk. = *Earlea speciosa* (Fries) Arth.
 3085 - " *S(i)milacis* L.v.S. = *Earlea speciosa* (Fries) Arth.
 †3094 - *Gymnosporangium Juniperi* Lk. = *Gymnosporangium germinale*
 (Schw.) Kern.
 †3095 - *Podisoma Juniperi* Lk. = *Gymnosporangium clavariæ-*
forme (Jacq.) DC.
 †3096 (504) " *macropus* L.v.S. = *Gymnosporangium Juniperi-*
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IMPROVE THE POTATO CROP¹

By A. G. Tolaas, Division of Agricultural Extension; Richard Wellington, Division of Horticulture; and G. R. Bisby, Division of Plant Pathology and Botany

GROW STANDARD VARIETIES

Grow the varieties of potatoes recommended for the various soils and market requirements of Minnesota. Grow only one or two varieties in any one community. Other varieties may eventually either take the place of those recommended or be added to the list, but such changes will and should occur slowly. No new variety or seedling will be recommended unless it proves superior after careful tests, to the varieties now recommended. The eight varieties may be divided roughly into early and late kinds.

Early Ohio is the leading early variety and is grown extensively for table use in the sandy soils north of the Twin Cities and for seed in the loam of the Red River Valley. Triumph and Irish Cobbler are also early and are grown as seed stock for the South. Triumph is subject to tip-burn and consequently is well adapted to the northern part of the state where there is not much danger of drought and hot weather. Irish Cobbler is rapidly gaining in favor in the northern part of the state but is handicapped by its similarity to the late round varieties.

Rural New Yorker stands first among the late varieties. Unfortunately it is often confused with Green Mountain, altho the two varieties are distinct in habit of growth and many other characters. Rural New Yorker is more subject to hollow center, in rich soils, and is more resistant to hot weather, and is therefore well suited to the southern and older sections of the state. Green Mountain, on the other hand, is well adapted to the cool climate and new soils of the northern part of the state. Burbank and Burbank Russet are late potatoes of fine quality and are especially adapted to rich, friable soils well supplied with humus. King, another late potato, is recommended only for sandy and poor soils, since it becomes irregular and develops deep eyes in rich soils.

¹ This bulletin is intended to take the place of Special Bulletins Nos. 5 and 22.

Description of Varieties

Early Ohio. Early Six Weeks, Ohio Junior, Acme, Early Market, and Prize Early Dakota are similar if not identical.

Tubers: Oval with rounded seed and stem ends; eyes numerous, shallow, sometimes protuberant; skin pinkish or flesh-colored, especially around eyes of seed end, usually with conspicuous corky dots or lenticels.

Sprouts: Stems medium in number, rather stout, angular, considerably branched, light green faintly tinged with purple; leaves dark green with leaf stalk tinged with purple; flowers white, borne on stalk situated in axil formed by leaf and stem.

Triumph. Noroton Beauty, Quick Lunch, Red Bliss, Bliss Triumph, and Stray Beauty are similar if not identical.

Tubers: Roundish, blocky, with blunt ends, slightly flattened; seed-end strongly depressed; cavity at stem end deep to very deep, irregular; eyes medium, numerous, rather deep; skin red.

Sprouts: Slightly tinged with red, tips reddish.

Plant: Stems medium numerous, stout, slightly angular, well branched, light green faintly tinged with purple; leaves dark green, petiole of leaves and leaflets tinged with faint purple; flowers light lavender.

Irish Cobbler. Early Eureka, Early Petoskey, Early Victor, and Hamilton Early are similar or identical varieties.

Tubers: Roundish, with blunt ends, slightly flattened; seed end depressed; stem end with large, broad, deep cavity; skin white; blocky shape and recessed ends are characteristic.

Sprouts: Tinged with considerable pink; tips light carmine.

Plants: Somewhat spreading; stems numerous, stout, considerably branched, light green, distinctly purplish at base; leaves dark green; flowers lavender fading to light lavender or whitish at maturity or in intense heat.

Rural New Yorker. Sir Walter Raleigh, Carman No. 3, and Rural New Yorker No. 2 are similar if not identical.

Tubers: Nearly round, considerably flattened, very broad, varying to oblong; eyes fairly numerous, shallow; skin white, slightly flaked at seed end.

Sprouts: Tinged with purple, tips purple.

Plants: Stems at first upright and appear weak, later become stout and spreading, heavily tinged with purple. First leaves appearing above ground purple on lower surface, foliage dark green; flowers few, purplish, usually dropping off, borne on bare stalk usually arising a short distance above the leaf axil.

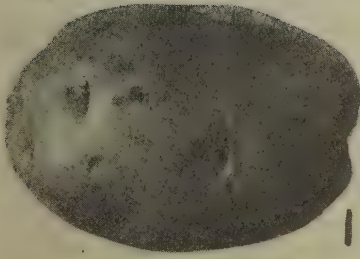
Green Mountain. Carman No. 1, Empire State, Gold Coin, Green Mountain Jr., Gurney, Norcross, State of Maine, and Uncle Sam are similar if not identical.

Tubers: Oblong, flattened, with blunt ends; eyes medium in number, shallow; skin white, slightly flaked.

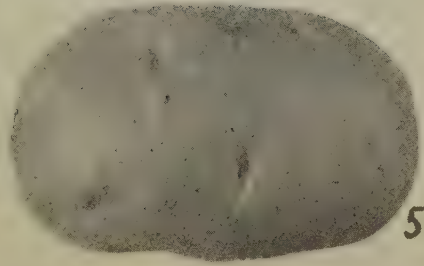
Sprouts: White with yellowish tips.

Plants: Unlike Rural New Yorkers make a strong bushy growth when young; very large, moderately compact, mostly decumbent; stems green, angular; foliage light green; flowers white, very numerous, borne on leaf petiole with one, two or three leaves.

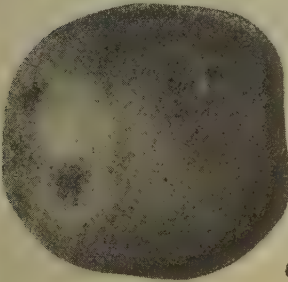
Burbank. Burbank Seedling. Frequently confused with White Chief, White Star, and Pingree which are inferior varieties.



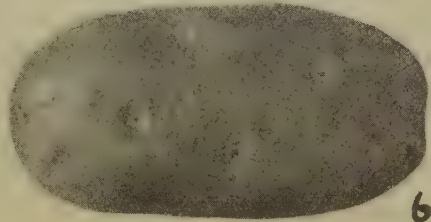
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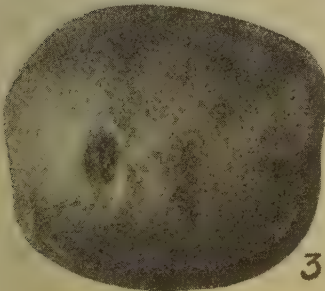
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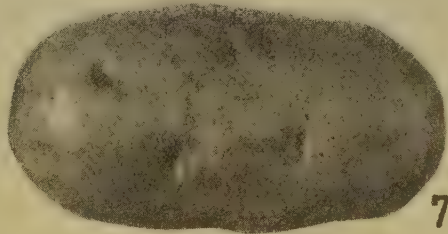
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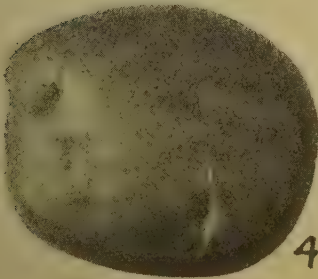
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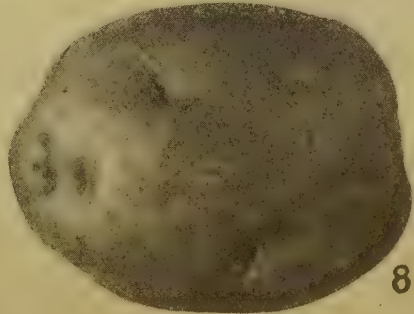
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Fig. 1. Eight Standard Varieties for Minnesota

No. 1 Early Ohio
No. 2 Bliss Triumph
No. 3 Irish Cobbler
No. 4 Rural New Yorker

No. 5 Green Mountain
No. 6 Burbank Russet
No. 7 Burbank
No. 8 King

Tubers: Long, cylindrical to slightly flattened with roundish ends; eyes medium in number, very shallow to slightly protuberant; skin white.

Sprouts: Tinged with pink, especially at base; tips very slightly carmine.

Plants: Large, bushy, fairly erect; stems numerous, rather slender, angular, light green faintly tinged with purple; leaves moderately dark green; flowers white with flowering habit similar to that of Green Mountain.

Burbank Russet. Similar to if not identical with California Russet, Cambridge Russet, Netted Gem, and Scabproof.

Similar to Burbank in all characteristics except netted or russet skin.

King. Similar to if not identical with Maggie Murphy.

Tubers: Broad oblong, flattened, blocky, with blunt ends; eyes rather numerous, medium to deep, pinkish; skin reddish, with deepest color at seed end.

Sprouts: Tinged slightly with pink, tips carmine.

Plants: Very large, bushy, mostly erect, giving row broad flat appearance; stems very numerous, stout, angular, light green tinged with purple; leaves medium dark green; upper side of leaf and leaflet petioles tinged purple; flowers white and nearly always drop before opening.

SELECT THE RIGHT KIND OF SEED

Select potatoes that show vigor, health, and high yielding qualities. This can best be done at digging time. Superior strains have been developed in some varieties as a result of careful selection, and show uniformity, vigor, and health. It does not pay to attempt to build up a poor strain by selection.

If the strain grown is unsatisfactory, get a better one. The past performance of a strain is a good indication as to what it will do in the future.

Do not introduce disease into the soil with the seed. Exclude disease when selecting potatoes. Select only healthy potatoes and treat the seed.

Discard tubers showing rots or brown discolorations either within the tuber or at the stem end. Such tubers, as well as knobby, irregular, "off shape," and very small ones, can be eliminated in the process of sorting, racking, and cutting. It may not be practicable to select individual choice tubers for the general field, but this should be done for the seed plot.

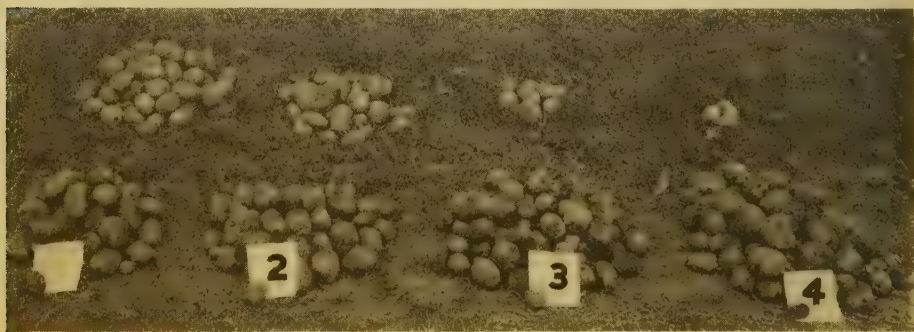


Fig. 2. Rural New Yorker Variety:

Front Row, Tubers With Black Scurf; Back Row, Clean Tubers

1. Crop from seed treated with corrosive sublimate, 1 sq. rod.
2. Crop from seed treated with copper sulphate, 1 sq. rod.
3. Crop from seed treated with formaldehyde solution.
4. Crop from untreated seed.

Treat the Seed

Tubers showing scab or black scurf on the surface should be treated with corrosive sublimate. This treatment is valuable because it cleans the seed. Formaldehyde has been recommended but is not so effective as corrosive sublimate especially for black scurf and blackleg.

Results in 1918 thus gave clear cut evidence of the value of corrosive sublimate as a disinfectant for potatoes showing black scurf. The four years' results show also that copper sulphate is of value under University Farm conditions. It is worthy of trial in other parts of the state. Formaldehyde solution, while of some value, is not recommended; results secured in seed plot work throughout the state have shown that it is unsatisfactory. Soaking for half an hour did not give, in 1918, as good results as treatment for two hours. We feel justified in recommending treatment of seed for from one hour to two hours.

Table I indicates the value of different seed treatments for black scurf.

TABLE I. VALUE OF DIFFERENT SEED TREATMENTS FOR BLACK SCURF

Kind of Tubers	Treatment	Strength	Time	Percentage of crop free from black scurf	
				Av. 3 plots, 1918	Av. for 4 years
Affected with black scurf	Corrosive sublimate..	4 ounces to 30 gallons water	Hours 2	73.5	57.4
	Copper sulphate.....	3 pounds to 50 gallons water	2	60.1	58.5
	Formaldehyde solution	1 pint to 30 gallons water...	2	47.3	46.2
	Check, no treatment.	.....	.....	16.9	23.0
	Check.....	.....	.....	92.8	....
Clean	Check.....	.....	.....	.....	.....

As the lower line in the table indicates, planting perfectly clean tubers (even without treatment) gives the best results. It must be remembered, too, that treatment does not "cure" diseases borne in the seed, or help build up "run out," "off type," or poor strains of potatoes. **Seed treatment must be combined with sorting, seed selection, and removal of undesirable hills during the growing season, crop rotation, and other good farm practices.**²

Barrels may conveniently be used for treating potatoes. Make holes near the bottom to draw off the solution when through treating.

Make corrosive sublimate solution by mixing four ounces of the sublimate with 30 gallons of water. Dissolve first in a small quantity of hot water, then add it to the remainder of the water. Keep treated potatoes away from livestock, as corrosive sublimate is a deadly poison.

Do not allow metals to come in contact with the corrosive sublimate solution, for it injures them. Soak the seed for about an hour and a half. Use the solution three or four times.

Dry the potatoes after treatment. Seed potatoes are sometimes injured by being allowed to remain wet after treating. The seed may be cut at once and then allowed to dry, or the seed may be cut first, then treated, then allowed to dry, or planted at once.

Use clean bins, sacks, baskets, or other containers to avoid contamination after the potatoes are treated or cut. The bin should be scrubbed out

² See "Selection and treatment of seed potatoes to avoid disease." B.P.I., C., T., & F.C.D. Cir. 3, and "Growing high-grade potato seed stock," C., T., & F.C.D. Cir. 5, for further information. They may be obtained free of charge from the Division of Publications, U.S. Dept. of Agr., Washington, D. C. Circular 3 may also be obtained from the Division of Plant Pathology and Botany, University Farm, St. Paul, Minn.

with a disinfectant (1 pint formaldehyde to from 10 to 15 gallons of water; or 1 pound copper sulphate to 10 gallons of water).

For small plots, that is, plots that may be planted by hand, sun-sprouted seed may be used. Seed potatoes are put where the sun or bright daylight will strike them until short, tough, green sprouts are formed. These come through the ground sooner than those planted before they sprout. Discard tubers that do not show vigorous sprouts.

Cut the Seed Carefully

Cut the seed by hand. Discard diseased and undesirable tubers when cutting. Rots may spread from diseased tubers to clean ones with which they come in contact.

Sulphur dusted over cut seed aids in drying the pieces and is of some value as a disinfectant. Put cut seed only in a clean bin, allow it to dry off soon, shovel it over, spread it thin. With careful handling, seed may be kept from one to three weeks after cutting.

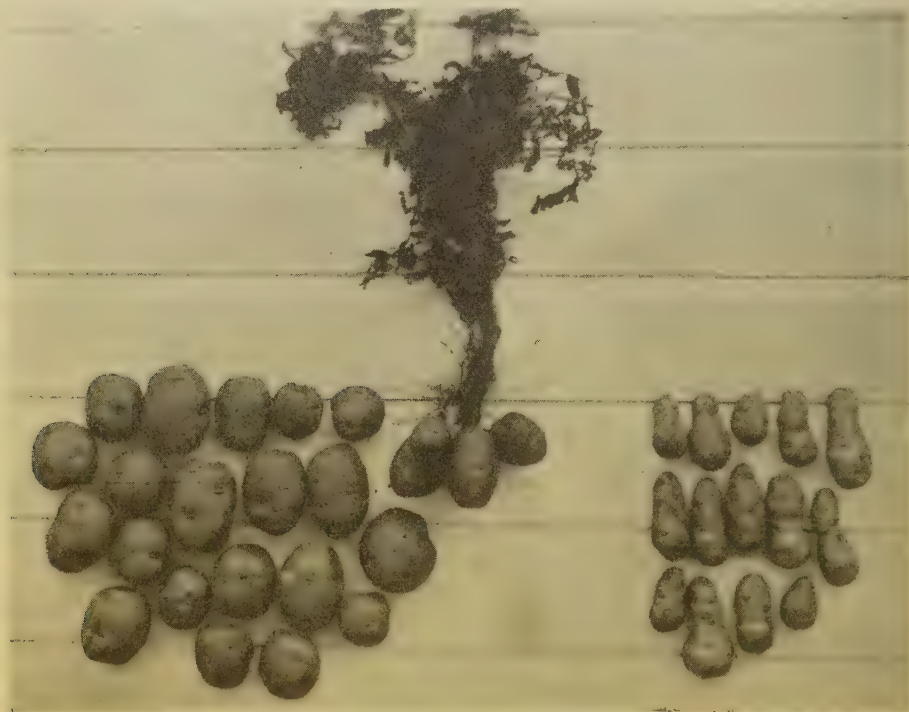


Fig. 3. The Value of Careful Selection

Potatoes at left represent actual yield from four hills of Green Mountain potatoes. Note true-ness to type. The hills at right represent the yield from four hills of the same variety taken from another field. Most of the field from which the latter were taken produced such tubers.

ROTATE CROPS

Do not grow potatoes on the same soil year after year. A five- or six-year rotation arranged so that potatoes will follow clover or alfalfa sod is ideal. By the use of such a rotation the accumulation of diseases is prevented, humus is added, and the soil is given an opportunity to replenish elements removed by the tubers. Rotation of crops will increase the yield of potatoes and improve the fertility of the soil. The figures below show results obtained on rotation plots at University Farm:

Character of rotation	Average percentage of black scurf
Potatoes continuously (4th year)	35.4
3-year rotation	1.7

Clean seed was planted and the black scurf present on the crop must have come from the soil. Continuous cropping to potatoes allows the accumulation of disease organisms in the soil.

PRACTICE PROPER CULTURAL METHODS

Plow deep for potatoes. The plants can not grow vigorously without plenty of loose soil. Do not, however, add more than an inch to the depth of plowing each year.

Do not plant too early. Cold wet soil may cause the seed to rot.

Practice clean cultivation, more vigorous plants result. The absence of weeds means better air circulation and less danger from blights.

MAINTAIN A SEED PLOT

Demonstrations carried on in Minnesota show the value of establishing and maintaining a seed plot. Table II shows what can be done by a little attention to seed selection and disease control.

TABLE II. RESULTS OF SEED SELECTION AND DISEASE CONTROL

County	Date	Number of plots	Average yield in seed plots per acre	Average yield of fields per acre	Average increase in yield per acre
			Bushels	Bushels	Bushels
Hennepin.....	1915	9	192	162.5	29.5
Otter Tail.....	1916	9	118	95.0	23.0
Clay.....	1917	6	101	72.0	29.0
Clay.....	1918	7	132	95.0	37.0
Kittson.....	1918	7	138	121.0	17.0

Altho some of the individual differences were small, the tubers produced on the seed plots were always of much better quality and more nearly true to type and were freer from disease.

Similar results can be obtained by establishing and maintaining a potato seed plot. Select a piece of ground in which potatoes have not been grown before. Select the seed to be used in this plot carefully with regard to type and freedom from disease.

By careful selection, control of diseases, and good cultural practices, and by growing varieties best suited to local conditions, an increase in yield of from twenty-five to fifty per cent and a great improvement in quality may reasonably be expected.

Keep up the practice of growing a seed plot every year. Select seed for next year's seed plot at digging time, when the yield from each hill can be easily determined. This is best done by hand, only tubers from productive vines, uniform, true to type, free from bruises and diseases, and weighing 7 or 8 ounces, being kept for the seed plot. After sufficient seed has been selected for next year's seed plot, the rest of the tubers should be kept for general planting. Avoid the use of misshapen and rough potatoes for seed. Handle seed stock carefully to avoid bruising or injuring, as bruised potatoes are more likely to rot than sound ones.

Avoid using any tubers that show a tendency to "run out." It is a good policy to discard all such stock and to obtain seed from some grower who has a good, heavily producing strain of the desired variety. Treat the

selected tubers in a solution of corrosive sublimate as described under "Treatment."

Rogue the seed plot carefully at blossoming time. This means remove all undesirable plants, such as varietal mixtures, weak and diseased plants.

Spray the seed plot thoroly.

SPRAY FOR INSURANCE

Write to the state entomologist, University Farm, St. Paul, for Circular 47, Some Insects Injurious to the Potato, by S. A. Graham.

Spray with paris green, 1 or 2 pounds to 50 gallons of water; or with lead arsenate, $1\frac{1}{2}$ pounds of powdered or 3 pounds of paste to 50 gallons of water, for beetles ("bugs").

Spray with bordeaux mixture to avoid blight and to increase yields. The tests in 1918 completed ten years' work in spraying with bordeaux mixture at University Farm. Spraying with 5-5-50 bordeaux mixture has, as the average for the ten-year period, increased the yield at the rate of 53 bushels per acre over the yield from the unsprayed check plots. The experiments have shown that to increase yield it is only necessary to keep some of the bordeaux mixture present on the leaves with about three thoro sprayings, beginning when the plants are about a foot high. The 5-5-50 bordeaux mixture has been found to be better than weaker strengths or the commercial preparations tried. Increased yield resulted whether late blight was present or absent, altho of course bordeaux mixture is particularly valuable in protecting potato plants against late blight.

In soil in which potatoes grow better than they do at University Farm, such striking increases in yield from spraying may not occur. This was indicated in tests carried out in Hennepin County in 1918. It is realized, too, that the use of bordeaux mixture requires some extra labor, which is an important factor at the present time. However, by preventing or lessening blights (late and early) and tipburn, and by keeping the leaves green and vigorous longer in the fall, its use pays. On certain types of soil not so well adapted to potatoes, as at University Farm, its use may result in a large increase in yield. Spraying with bordeaux mixture is important in growing better potatoes.

Make bordeaux mixture from 5 pounds of copper sulphate, 5 pounds of lime, and 50 gallons of water. Dissolve the copper sulphate by hanging it over night, in a sack, near the top of 25 gallons of water; slake the lime in a little water, and add enough to make 25 gallons; stir the two solutions, pour together, and use the same day. On a larger scale, use stock solutions.

Spray with bordeaux mixture two to four times, depending on weather conditions, beginning late in July or early in August. Use any sprayer that gives a high pressure and a fine spray.

Paris green or lead arsenate may be combined with bordeaux mixture if potato beetles are still prevalent.

STORE POTATOES PROPERLY

Provide a cool, dry, well-ventilated cellar or storage house for potatoes. A warm, damp cellar furnishes good conditions for the development of rots. Keep the seed tubers for next year in separate bins. Keep the temperature as close to 35 or 40 degrees, Fahrenheit, as possible. A temperature above 40 degrees will cause the tubers to sprout too early and cause considerable injury to the seed through the loss of sprouts when handled.

The University of Minnesota

AGRICULTURAL EXTENSION DIVISION

*Given to J. H. March
St. Paul, Minn.*

Smut Treatment for Grains



Published by the University of Minnesota, College of Agriculture, Extension Division, A. D. Wilson, Director, and distributed in furtherance of the purposes of the coöperative agricultural extension work provided for in the Act of Congress of May 8, 1914.

THINGS TO

1. Use formaldehyde of standard (37-40%) strength.
2. Clean grain thoroly before treating to get rid of smut balls and smut masses. Use the fanning mill.
3. Clean floors, bins, wagon boxes, sacks, drills, coverings or anything with which grain may come in contact after it has been treated. Clean any or all these by washing or soaking thoroly with some of the solution used for treating the grain.
4. Keep grain from freezing after it has been treated. Sow the day following treatment or spread out and shovel over every few hours until dry.
5. Avoid heating of grain by sowing it, or by drying the seed as quickly as possible after it has been treated. If drying can be done in sunshine it is faster and better.

REMEMBER

6. If treated grain is sown before thoroly dry, set drill to sow from one-fifth to one-fourth more per acre than when dry grain is used.
7. Get smut-free seed if loose smut of barley or wheat has been troublesome. The treatment given herewith is not effective for loose smuts.
8. Treat this year if your grain was clean. The threshing machine may make the clean grain foul. Formaldehyde will make the foul grain clean.
9. Minnesota's smut tax in 1918 was \$8,000,000. Your share was ? ? ?

TREAT, ENTREAT OTHERS TO TREAT!

10. Call upon the Farm Bureau Committeemen or the County Agricultural Agent for a demonstration in your neighborhood. The County Farm Bureau office is always at your service.

Grain Smuts Lose Dollars for You

Formaldehyde will Stop the Loss

Will YOU use it this year?

There are four methods about equally effective that may be used. Which one to use will depend on convenience and equipment on the farm.

The **dipping method** is that in which the grain is put into the prepared solution and soaked for a short time.

The **machine method** requires the purchase of a smut-treating machine.

The **spraying method** can be recommended at the present time only for oats.

The **sprinkling method** is the simplest and most common and may be used under the greatest variety of conditions. For that reason it is outlined herewith:

The **sprinkling treatment** is effective for oat smut, bunt or stinking smut of wheat, covered smut of barley, and rye smut. Pour one pint of standard formaldehyde (37% to 40%) into forty gallons of water and stir thoroughly. Spread grain to be treated in a layer not more than four inches deep. Use a clean floor or wagon box. While one person turns the grain by shoveling a second person sprinkles it slowly using an ordinary sprinkling can. The sprinkling should continue only until all the seed is moist. Shovel the grain into a cone-shaped pile and cover with clean sacks, carpets or a tarpaulin from four to six hours or over night. The forty gallons of solution should treat about fifty bushels of grain.

Note the precautions on the other side of this card.

It pays—Use a fanning mill on the seed grain before treating if you can. It helps!

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

STUDIES ON FUSARIUM DISEASES OF POTATOES AND TRUCK CROPS IN MINNESOTA

TECHNICAL

BY

G. R. BISBY

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Section of Seed Laboratory

- R. C. DAHLBERG, B.S., Seed Analyst, Acting in Charge
A. H. LARSON, B.S., Assistant Seed Analyst

* On leave of absence.

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STUDIES ON FUSARIUM DISEASES OF POTATOES AND TRUCK CROPS IN MINNESOTA

By G. R. BISBY

INTRODUCTION

Fusarium wilt was reported (72) as causing a loss of more than twenty-five million bushels, or 4.54 per cent of the potato crop of the United States in 1917. Despite the large damage due to *Phytophthora infestans* in this country the same year, the total loss reported from Fusarium wilt was greater. Besides the injury from wilt, Fusarium tuber rots in the field, in storage, and during transportation may destroy from 10 to 50 per cent of the crop (37, 43, 72, 75).

Minnesota is one of the states in which typical Fusarium wilt has been serious. Certain symptoms atypical of wilt have also been under observation for some time, particularly in the Red River Valley. The study of this rather anomalous disease has received particular attention. Fusarium dry rot was also found to present, in Minnesota, certain phases not emphasized heretofore. The writer has also studied certain Fusarium diseases of other truck crops as well as those of the potato.

The genus *Fusarium* was established by Link in 1809 (34). Various changes in the use of generic and specific names for the fungi in question were made during the succeeding century; the species added were often imperfectly described, and the host or substratum served frequently as the chief distinguishing diagnostic character. Smith and Swingle in 1904 (63) were forced to revert to the oldest available name to designate the Fusarium on potato, viz., *F. oxysporum* Schlechtendal, 1824. Appel and Wollenweber in 1910 (2) published a monograph of the genus *Fusarium*, and were able accurately to define several species. The literature to the year 1910 is also summarized. Wollenweber (76), Lewis (32), Sherbakoff (59), and others have also worked intensively on the Fusarium problem and described several new species. The name *Fusarium oxysporum* is, however, still applied to the fungus commonly causing wilt of potatoes.

MATERIALS AND METHODS

Isolations were made during the summers of 1916, 1917, and 1918 from potato plants showing various wilt symptoms. The plants were obtained from sections of Minnesota north of St. Paul, particularly

the Red River Valley region. Several cultures of *Fusaria* isolated in 1914 and 1915 were furnished by A. G. Tolaas. During the winters, isolations were also made from rotted potato tubers. Isolations were made from garden beans and peas, sweet corn, cucurbits, and tomatoes. Several hundred cultures were studied and numerous inoculations were made in the laboratory, in the greenhouse, and in the field in 1917 and 1918.

Various culture media were used, particularly rice and potato plugs, sweet clover stems, the common agars for dilutions, and 5 and 10 per cent dextrose agar for color reactions. The ordinary methods of technique were used unless otherwise stated.

The writer wishes to express his thanks particularly to Dr. E. C. Stakman and Dr. E. M. Freeman, under whom the work was done, for suggestions and supervision. The writer is also indebted to A. G. Tolaas and Dr. W. A. Orton for cultures and other help, and to Dr. C. D. Sherbakoff for tentative corroboration of some determinations. The writer is particularly grateful to Dr. H. A. Edson of the United States Department of Agriculture who in his visits to Minnesota has freely given information and ideas.

The writer has submitted cultures of the various unidentified *Fusaria* to Dr. Sherbakoff for such taxonomic disposition as he sees fit.

POTATO WILT

HISTORICAL

Smith and Swingle (63) made the first detailed study of the wilt of potato caused by *Fusarium oxysporum*. The dry rot of tubers discussed by them is now generally considered to be caused chiefly by other species of *Fusarium*. They described in detail the effects of the wilt fungus on the plant and its entrance into and spread within the tuber. They studied the behavior of the fungus on various media. Control methods for wilt were suggested. While the earlier publication of Stewart (65) on "Another stem blight of potato" deals with a disease similar to wilt, Stewart (66) decided in 1898 that the blight was not communicable and "not caused by any vegetable organism," and recently stated, in letters dated Nov. 18 and 30, 1918, "While the symptoms point to *Fusarium* wilt, I doubt that it was actually that disease." However, "If it is true that tubers showing pronounced discoloration of the fibro-vascular bundles, owing to the infection with *Fusarium* wilt, do not usually produce affected plants, then there is some reason for believing that my Long Island stem-blight was in reality *Fusarium* wilt. The tubers which were planted in my experiments were all very definitely affected by the stem-end browning.

Every piece planted showed the stem-end browning. Accordingly, it seems to me that more diseased plants should have resulted." Clinton's description in 1895 (11) of a "Bundle blackening of tubers" may have been of the ring discoloration caused by *F. oxysporum*. He wrote in a letter dated Dec. 3, 1918, "While the tubers mentioned may quite likely have been connected with such a wilt, I have no positive information that they were."

Orton in 1909 (40) reported that the accumulation of *F. oxysporum* and other fungi in the peat soils of sections of California soon made the growing of potatoes unprofitable. Manns (36), as a result of his work, recommended clipping the stem ends of infected tubers. This is now a commonly used control method. Orton in 1914 (42), in comparing wilt due to *F. oxysporum* with leaf roll and other diseases, considered that wilt was "apparently a disease of warmer climates," altho he recognized that "in Minnesota wilt appears to be present in the older communities."

Discussing the occurrence of this disease in Europe, Appel (1, p. 143) states, "The [wilt] disease occurs in Germany also, but is of much less importance." Nicholls (38) reported the presence of *F. oxysporum* in Tasmania, and Carpenter (10) found this fungus in potato vines and tubers in Hawaii. Reports of *F. oxysporum* from other countries are doubtful, since this name has been loosely used.

Jones (27) found potato wilt especially in the older communities in Wisconsin. Milbrath (37) noted its seriousness in North Dakota, and its importance in Minnesota has been recognized for some time by Stakman and Tolaas (64). Kohler (30) may have referred to the stem end browning caused by *F. oxysporum*, tho it may be inferred that dry rot of tubers was also involved in the rot he attributed to "an undetermined species of *Fusarium*."

Carpenter (8), Link (33), and others have shown that *F. oxysporum* can produce a rot of potatoes. This is not in agreement with Wollenweber's (76) conclusion that members of the *Elegans* section of the genus *Fusarium* cause wilt but not rot. *F. eumartii* Carpenter, belonging to the section *Martiella* (76, p. 30), has been found by Haskell (20) and C. R. Orton (39) to cause a stem rot and wilt of potato plants, as well as a rot of the tubers. "Potato wilt" may, therefore, be due to more than one species of *Fusarium*, possibly following certain geographical limits. Orton (42) reported the symptoms of *Verticillium* wilt to be similar to those of *Fusarium* wilt and stated that the distribution of the former was restricted more particularly to the northern states. *Verticillium* wilt is reported (72) to be especially serious in Oregon. Appel (1) has noted (referring presumably particularly to Minnesota) symptoms atypical of the common potato wilt.

SYMPTOMOLOGY OF POTATO WILT CONDITIONS IN MINNESOTA

The symptoms have been fully described by other writers, and in general agree with those found under Minnesota conditions. Coons (13) recently noted that in Michigan the disease may exhibit two aspects; one, a rapid wilting in which the vine dies when the tubers are about half grown; and another characterized by the dying of the plants "at the close of the growing season." He found these symptoms to depend perhaps on whether the infection is from the seed piece or from the soil.

Figures 1 and 2 show the wilt symptoms common in Minnesota fields. Except in more severe cases, the plants do not begin to wilt until about blossoming time or later. The symptoms on the upper part of the plants are apparently those resulting from a considerable reduction in water supply. A cross-section of the lower stem reveals the browning of the vascular system and often of the other tissues as well. This browning may extend to the tips of the plants, tho the bundles are often free from hyphae in these upper discolored areas. The roots are usually affected seriously. The tubers, which have ordinarily had an opportunity to develop considerably before the wilting of the plant stops their growth, may be affected at the stem end, as fully described in the literature.

Atypical wilt symptoms such as those mentioned by Appel (1, p. 147) have received particular attention. Other observers had noticed these atypical symptoms, particularly in 1914 and 1915 in the Red River Valley, and had considered that they might be caused by the blackleg organism or some species of *Fusarium*. For convenience the term "foot rot" will be used to indicate the condition in question. The writer found some of this disease in 1916, practically none in 1917, but in August, 1918, it was found in Polk and Clay counties in the form more characteristic of that seen by Appel, Edson, Stakman, Orton, and others in 1914 and 1915.

Plants affected with foot rot are shown in Figures 3, 4, and 5. There is a dark brown or almost black discoloration of the lower and underground portions of the stem. These discolored areas are often rotted. When secondary organisms are present there may be a typical soft rot. While the symptoms resemble those of blackleg somewhat, there is not the inky black, slimy rot characteristic of blackleg. The disease is, however, confused with blackleg by growers and others.

There is a more abundant development of hyphae in the primary vessels and other tissues of the stem than in stems affected with ordinary wilt. The effect on the roots and stolons is similar to that on portions of the lower stem (see Figure 5). The stem end of the

tuber may be attacked, and the way paved for invasion by secondary rotting organisms. The above-ground portions of the plant successively wilt, die, and eventually collapse. Fortunately this foot rot occurs more particularly late in the season, as is also ordinarily the case with wilt in Minnesota, so that a considerable crop of tubers may already have been produced. These tubers are, however, liable to suffer considerable injury before or during storage from the invasion of *Fusaria* and other organisms through the injured point of attachment of the tubers to the affected stolons.

The relation of this foot rot in Clay County, Minnesota, to the weather (United States Weather Record, Moorhead Station) during the 5 years this condition has been under observation is shown in Table I.

TABLE I
RELATION OF WEATHER TO THE DEVELOPMENT OF FOOT ROT

Year	Precipitation				Average temperature				Notes on the disease
	May	June	July	August	May	June	July	August	
	Inches	Inches	Inches	Inches	Degrees	Degrees	Degrees	Degrees	
1914	1.47	8.92	3.65	2.89	57.4	64.8	73.1	65.0	Abundant
1915	3.93	9.13	2.22	1.05	51.7	59.2	65.2	65.2	Present
1916	3.76	4.28	5.30	2.87	53.0	60.3	75.9	67.2	Present
1917	0.38	1.52	0.81	0.77	53.6	61.3	75.2	66.4	Absent
1918	2.73	1.79	2.68	4.90	55.0	64.4	67.7	69.4	Present late in season
Normal	2.95	4.13	3.74	3.10	54.8	64.14	68.7	65.9	

More than double the normal precipitation occurred in June, in 1914 and 1915. The rainfall was especially heavy in July, 1916. The season of 1917 was very dry, while in 1918 it was dry until late July and early August, when there was considerable precipitation. Moderately high temperature is also undoubtedly a factor in producing *Fusarium* wilt, altho, as shown by the temperature in July, 1917, the atypical foot rot does not occur as a result of high temperature without abundant rainfall; and as indicated in 1915, these symptoms may appear in a year of high precipitation even with temperatures considerably below normal. Observations indicate further that foot rot attacks the plants seriously only later in the season, even tho weather conditions from planting time on have been favorable to its development. Kohler (30) described *Fusarium* diseases of potato in Minnesota, and the foot rot condition may have been involved. He stated that "This disease does great havoc in wet years." Poor yields were obtained from planting tubers showing rot.

ETIOLOGY OF WILT OF POTATO IN MINNESOTA

The fungi isolated from various parts of wilted plants, particularly the interior of the stem near the surface of the soil, from several regions in Minnesota, especially the Red River Valley, were predominantly *Fusaria*. *Verticillium* was obtained in only a very few cases, and then in association with other organisms, indicating that it was only saprophytically or accidentally present. There was no evidence that *Verticillium* wilt is important in Minnesota. Most frequently the cultures obtained were determinable as *Fusarium oxysporum* by the character of their conidia, the salmon to lilac color of the medium (potato or rice), the dark bluish green sclerotia, and the buff sporodochia. As was to be expected, contaminations were sometimes present, and other *Fusaria* than *F. oxysporum* developed occasionally. Sometimes the difficulty in obtaining a "high culture" (Appel and Wollenweber 2, p. 22) of the *Fusarium* rendered identification somewhat less certain, owing to the paucity of macroconidia produced, or to the suppression of some other distinguishing character. The cultures were, however, run along with authentic *F. oxysporum* obtained originally from Wollenweber's laboratory (Nos. 3315 and 3394) through the courtesy of Dr. W. A. Orton. Specimens were also submitted to Dr. C. D. Sherbakoff for identification.

Ordinary wilt of potato in Minnesota appears, then, to be due, at least predominantly, to *Fusarium oxysporum*. This fungus has also been isolated several times from tubers showing brown ring discoloration. It was thus obtained from tubers grown as far north as Kittson County, in the extreme northwestern corner of the state.

ETIOLOGY OF FOOT ROT

Isolations were made from numerous wilted plants showing atypical wilt symptoms in the expectation that organisms other than *F. oxysporum* were the causal agents. Some isolations obtained by A. G. Tolaas from atypically affected plants in 1914 and 1915 were identified by the writer. The fungus obtained from plants showing foot rot symptoms was found in the majority of cases to be *F. oxysporum* and, as already indicated, the unusual appearance is attributed particularly to the heavier precipitation resulting in a watersoaked condition of the soil. This is most likely to occur in a heavy soil such as that in the Red River Valley. Other fungi and several bacteria were also isolated, but all the evidence indicated that they were merely saprophytes.

OCCURRENCE OF *FUSARIUM OXYSPORUM* IN POTATO PLANTS

In the course of development of the wilt or foot rot disease, considerable amounts of the infecting fungus are of course accumulated in the tissues of the potato stems, roots, stolons, and even in the tubers.

The following observations indicate that the fungus may grow on other parts of the plant also, and develop in greater abundance on those parts mentioned.

On vines affected with wilt in the field and placed two or more days in a moist place, a luxuriant growth of fungus may develop. (See Figure 4.) From the surface and the interior of these vines, *F. oxysporum* was isolated. Not infrequently the mycelium and spores of *F. oxysporum* may have developed abundantly in the somewhat hollow areas within the stem of plants affected in the field. Plants affected with wilt or foot rot may thus cause heavy contamination of the soil.

Isolations were made on September 10, 1917, to determine if *F. oxysporum* might be present more or less saprophytically in the stems of plants late in the season. This was shortly after a frost had practically destroyed the leaves. These plants had been grown at University Farm, part of them from northern grown seed, had not shown signs of wilt, and had produced a good crop of healthy tubers. Below the surface of the soil the inside of these stems was browned, and from some such stems "high cultures" of *F. oxysporum* were readily obtained. Similar isolations were made later in 1917, and several on October 1 and 2, 1918. The isolations made in 1918 were from the old stems of normal plants which had been killed by frost. They were taken from a field in Hennepin County which had been sprayed with bordeaux mixture, and which had yielded 214 bushels per acre. *F. oxysporum* was obtained consistently from this material.

The "dry stem rot" of potatoes with which *Rhizoctonia* is associated is common in Minnesota. That *Fusarium oxysporum* may occasionally be a factor in causing this condition is indicated by the fact that it was isolated from the external stem lesions of plants affected with "stem rot," as well as from the interior of such stems. The interior of potato stems affected with dry stem rot is often browned, especially near the base. Edson and Shapovalov (15) have shown recently that various fungi, including *F. oxysporum*, may cause stem lesions. *Rhizoctonia* hyphae may of course be present even if they are not the primary cause of the lesions.

The seed piece under the growing plant is often rotted. If the rot is caused by bacteria it is soft and foul smelling. Species of *Fusarium* may cause a dry rot. The rot of the seed piece may be soft and without a foul odor. Isolations were made in the season of 1917 from several such cases as the last two. The specimens were obtained from University Farm and other parts of the state. *F. oxysporum* was often obtained from seed tubers affected with soft rot. From tubers affected with dry rot, *F. discolor sulphureum* (Schl.) App.

and *Wr.* and other *Fusaria* were obtained. Bacteria and other fungi were of course commonly present as secondary organisms. No difficulty was experienced in securing a more or less soft rot of potato tubers with *F. oxysporum* by artificial inoculation.

Considerable mycelium of *F. oxysporum* may occur in and on the leaves of plants growing under moist conditions, even when the lower stem does not show the presence of the fungus. Such leaf infection may presumably result from inoculum carried by insects or spattered by rain. Milbrath (37) reports that leaves may be affected, altho he may have meant only internally. (See also 15.) Cases of external as well as internal infection of leaves and petioles have been secured from artificial infection in the greenhouse.

The relation of *F. oxysporum* to the soil is discussed in another section.

ARTIFICIAL INOCULATIONS WITH *F. OXYSPORUM* ON POTATO PLANTS

Many preliminary experiments in the greenhouse and in the field to secure infection and wilt of potato plants by artificially inoculating *F. oxysporum* into the seed piece planted, or into the soil, were unsuccessful. An examination of the literature indicates also that other workers have not had great success in securing infection of potato plants with the wilt organism under ordinary conditions. It is evident that *F. oxysporum* is not vigorously parasitic to actively growing potato plants.

Sometimes such results as shown in Figure 6 were obtained under greenhouse conditions. Rotting of the seed piece, browning of the stem, and death of the leaves ensued from inoculating the seed tuber with *F. oxysporum*. This is hardly characteristic of *Fusarium* wilt, however, tho resembling the foot rot condition.

In view of the possibility that the average temperature in the greenhouse during the winter months was not sufficiently high for good infection, the cage shown in Figure 7 was constructed, and heated with two carbon electric light bulbs. A soil temperature of from 20 to 30 degrees could thus be maintained. The humidity was of course also high. Figures 8 and 9 show a type of injury resulting from inoculating sterilized soil heavily with *F. oxysporum* under these warm and damp conditions. This injury was caused several times with *F. oxysporum*, and *F. radicola* Wollenw. caused a similar injury in one trial. Fitch and Bennett (17) illustrate a somewhat similar condition as found in the field. Link (33) also secured stem rots in the laboratory with *F. oxysporum*. Injuries such as are illustrated

in Figures 8 and 9 are considered entirely comparable with the naturally occurring foot rot condition illustrated in Figures 3 and 4.

Figures 10 and 11 show two infected plants resulting from a lighter infection of the soil, and are believed to represent a fair greenhouse manifestation of *Fusarium* wilt. It is to be noted that the upper leaves show the characteristic rolling (see 1, p. 143). The higher temperatures in the warm chamber, while allowing infection, were unfavorable to the potato. Plants placed inside the chamber died sooner than corresponding plants left outside.

FIELD STUDIES WITH SEED TUBERS FROM WILTED PLANTS

Wilted plants do not result from planting infected seed, unless conditions are favorable to the development of the fungus. These conditions, particularly a high temperature, are often at the same time unfavorable to the potato. Seed from vines wilted in the field, showing more or less of the bundle blackening, usually produced plants in the greenhouse similar to those from normal seed. Such seed planted in the field in 1917 in not seriously infected soil gave no more wilt than several plots from ordinary seed.

A fairly extensive study of the effect of planting tubers produced under wilted vines was made in the field in 1918. Late in the summer of 1917 several Green Mountain potatoes were dug by hand from under badly wilted vines in Clay County, Minnesota. There was no marked amount of stem end discoloration of the tubers at digging time, nor did this vascular browning increase appreciably through the winter. Through the courtesy of Dr. G. H. Coons, a half bushel of tubers was obtained in the spring of 1918 from a field in Michigan which had shown from 30 to 40 per cent of wilt. Plantings were made in the field at University Farm. The tubers from Clay County were planted whole, and those from Michigan were divided into two lots. Several isolations were made from one lot to determine the fungi present in the browned vascular tissue of the stem end of the tubers. *F. oxysporum* and various other *Fusaria* were obtained. The other lot was used for planting, and the tubers were sorted into two groups according to size. The smaller tubers were halved to give eye and stem ends, and the larger tubers were cut longitudinally through the former point of attachment of the stolon, then cut transversely, to give two each of approximately equal eye ends and stem ends. These were planted in two places on University Farm. The stand of the potatoes obtained from Michigan was poor, owing particularly to frost necrosis of the tubers (29) and to the fact that the "seed" had been obtained from seriously affected plants. It was also necessary to plant the tubers rather late in the spring. The seed pieces were planted 16½ inches apart in rows 3 feet apart.

The average yield of the tubers from Clay County was slightly more than one pound per hill ($29\frac{1}{2}$ pounds from 25 hills) or at the rate of 180 bushels per acre. The plants were not wilted. The yield indicates that the seed was not affected; indeed, it is possible that the greater immaturity of such seed resulted in added vigor of the progeny.

The results with the seed from Michigan are summarized in Table II.

TABLE II
RESULT OF PLANTING TUBERS FROM BADLY WILTED VINES

Character of seed piece	Date planted	Area of plot*	No. of wilted plants	Yield	Rate per acre
				Pounds	Bushels
Eye quarters	June 4	Sq. Ft. 268.5	0	32.0	86.5
Stem quarters	June 4	268.5	2	23.0	62.2
Eye halves	June 4	148.5	2	12.0	58.4
Stem halves	June 4	148.5	1	14.5	70.9

* Including proper marginal area about plot.

In 1918 a plot of the eight standard varieties (6) was planted, and a considerable amount of fungus from cultures of *F. oxysporum* introduced into the soil beside each seed piece at planting time. Here again only healthy plants were produced, indicating that none of the varieties is particularly susceptible to the fungus, unless other factors are conducive to the development of wilt.

The data presented in Table II indicate that serious disease does not necessarily follow from planting seed from wilted vines, and that no more wilt may result from the use of the stem ends than from the use of eye ends. Other observations support this view. Wilted plants do not, of course, produce tubers of as good quality as healthy plants, and it can not be denied that infected tubers may introduce more of the disease into the soil. Such seed is considerably less desirable than seed from healthy plants, and plants affected with wilt should be rogued from plots to be dug for seed. Selecting seed or clipping the stem ends is, however, not alone sufficient to avoid loss from wilt. The considerations involved in the use of affected seed from the north for planting in the southern states require further attention.

FUSARIUM DRY ROT OF POTATO TUBERS

HISTORICAL

Some of the earlier literature regarding *Fusarium* rots of potato, both American and European, is summarized by Smith and Swingle (63) and in part by Manns (36), altho these authors did not distinguish between the *Fusaria* causing dry rot and those causing wilt.

The monograph by Appel and Wollenweber (2) made it possible to distinguish between species of *Fusaria*. Jamieson and Wollenweber (25) reported *F. coeruleum* (Lib.) Sacc. and *F. discolor sulphureum* to occur in Germany as wound parasites, and the American *F. trichothecioides* Wollenw. was described and reported from Washington, Minnesota, Iowa, Nebraska, and South Dakota. Inoculation studies were described. *F. tuberivorum* Wilcox and Link (75) was considered a synonym of the previously established *F. trichothecioides*. Orton (41) in 1913 gave a brief description of this "powdery dry rot" and suggested methods of control. Wollenweber (76) distinguished sharply between wilt- and rot-producing *Fusaria*. Carpenter (8), besides showing that this sharp distinction did not hold for tuber rots, described *F. eumartii* as a new species of *Fusarium* causing dry and wet rot of tubers. He also reported *F. radiculicola* as producing tuber rot through wound infection. Pratt (49, 51, 52) showed that *F. radiculicola* and *F. trichothecioides* were apparently well distributed through the western desert soils, and suggested disinfecting the stock before storage or the use of cold storage, as a control measure against rot. Link (33) has shown that *F. trichothecioides* can cause wilt as well as rot, and also that *F. oxysporum* can cause rot as well as wilt. Sherbakoff (59) stated that the *Fusarium* most commonly producing potato rot in the eastern United States is *F. coeruleum*. Pethybridge (46, 47, 48), in Ireland, performed experiments with dry rot of potatoes which he considered due to *F. coeruleum*. Orton (39) and Haskell (20) have found that *F. eumartii* can cause, besides a tuber rot, a wilt or stem rot of the potato plant. Milbrath (37) reported dry rot to be serious in North Dakota, causing a loss of "over 20 per cent in all storehouses in the Northwest" in 1914. Altho he did not specify which *Fusarium* was responsible, it is noteworthy that Carpenter mentions having isolated *F. discolor sulphureum* from tubers sent in by Milbrath, as well as from tubers obtained from South Dakota. Other references to *F. discolor sulphureum* (2, 25, 59, 76) mention its presence in Germany, and nowhere has the writer seen it referred to as being serious in the United States.

DISTRIBUTION

In the United States, *Fusarium* dry rots appear to be widely distributed east and west, but the north central part of the country has not been very critically surveyed. In Minnesota, isolations have been made from tubers grown in Kittson, Pennington, Polk, Norman, Mahanomen, Clay, Wilkin, Otter Tail, Bigstone, Swift, and Lincoln counties, along the western side of Minnesota, and from Brookings County,

South Dakota. Some have also been made from the region of the Twin Cities and from Crow Wing and Kanabec counties.

SYMPTOMOLOGY

The *Fusarium* dry rot of potatoes found in Minnesota is a brown, compact, firm rot, without the foul odor of bacterial rots. Cavities are often present in the tissues. These cavities and the tissues contain considerable mycelium which develops readily and abundantly when the tuber is placed in a damp chamber. From the edges of the rotted areas, pure cultures of the fungus may usually be obtained directly from tissue cultures. The skin of the potato is often wrinkled. Figures 12, 13, and 14 show the appearance of this rot as found in storage. The rot starts at any point on the potato, and in the case of stored potatoes usually from a wound. It is more abundant as the winter advances. It does not have the powdery appearance characteristic of the rot caused by *F. trichothecioides*, because the spore masses when present are more compact and less dry.

Sections of rotted potato show that the fungus grows through the cells in considerable abundance. The observation of Orton (39) and Pratt (49) that a dry rot fungus has a tendency to follow the vascular system can be confirmed in tubers rotted by *F. discolor sulphureum*. The writer's experience in general corroborates Carpenter's observations (8) that there is no real distinction between the effects of *Fusaria* causing dry and soft rots, altho *F. discolor sulphureum* under ordinary conditions produces a dry rot.

ETIOLOGY

F. discolor sulphureum was obtained readily from affected tubers grown in many parts of Minnesota. Altho the fact that this *Fusarium* is the cause of a dry rot of potatoes has not been emphasized, it is one of the most common causes of rot in Minnesota, particularly in the Red River Valley. The ability of this fungus to cause dry rot has been demonstrated frequently.

EXPERIMENTAL

Efforts to determine varietal differences in susceptibility were unsuccessful. The eight standard varieties for Minnesota (Brown and Wellington, 6) were used, and rot developed from wound inoculations in each variety.

A series of experiments was made to determine the relations of injury to the tuber and of moisture and temperature to the development of the rot caused by *F. discolor sulphureum*. Tubers were inoculated on the uninjured epidermis, on the surface after slight wounding with

a sterile scalpel, and in deeper cuts into the tuber. Sets of inoculated tubers were kept at different temperatures under damp conditions, and similar sets in dessicators containing calcium chloride. The results are summarized in Table III. (See Figure 15.) The extent and rapidity of the rot is proportional to the seriousness of the injury to the tuber, tho the fungus may sometimes enter through uninjured surfaces, probably through lenticels. The later series of inoculations (December, 1918), incubated for 13 days (see Table III), resulted in less infection than in the previous experiments. A less vigorous "strain" of the *Fusarium* may have been used. There are characteristic differences in the rot developed at different temperatures. Under cooler conditions, the tissues are darkened and contain few "pockets" and few spores. It is evident that the fungus can rot tubers readily under dry conditions, especially if it gains entrance through wounds. The absence of wounds appears to retard the development of *F. discolor sulphureum* more than dryness or storage temperature, except in the case of cold storage.

TABLE III

EFFECT OF INJURY, TEMPERATURE, AND MOISTURE UPON THE OCCURRENCE OF THE ROT OF POTATOES CAUSED BY *F. discolor sulphureum*

Character of injury	Moisture	Temperature	Tubers inoculated	Time	Results
		Degrees		Days	
None	Saturated	1.1-1.7	4	30	No rot
	Saturated	8-10	4	12	No rot
	Saturated	8-10	9	13	No rot
	Dessicator	8-10	4	12	Slight rot in some cases
	Dessicator	8-10	8	13	No rot
	Saturated	Room	4	12	Slight rot in some cases
	Saturated	Room	8	13	No rot
	Dessicator	Room	6	12	Slight rot in some cases
	Room humidity	Room	4	12	Slight rot in some cases
	Saturated	25	6	13	No rot
Slight	Dessicator	25	6	13	No rot
	Saturated	1.1-1.7	4	30	Trace rot
	Saturated	8-10	4	12	Moderate rot on all
	Saturated	8-10	9	13	Slight rot on 3 tubers
	Dessicator	8-10	4	12	Moderate rot on all
	Dessicator	8-10	8	13	Slight rot on 4 tubers
	Dessicator	Room	6	12	Moderate rot on 4 tubers
	Saturated	Room	4	12	Moderate rot on all
	Saturated	Room	8	13	Slight rot on 2 tubers
	Saturated	25	6	13	Slight rot on 2 tubers
Considerable	Dessicator	25	6	13	Slight rot on 3 tubers
	Saturated	1.1-1.7	8	30	Slight rot
	Saturated	8-10	6	12	Much rot on all
	Dessicator	8-10	6	12	Moderate rot on all
	Dessicator	Room	4	12	Much rot on all
	Saturated	Room	4	12	Much rot on all
	Room humidity	Room	4	12	Much rot on all
	Saturated	25	5	12	Much rot

Pethybridge (47) has reported that young sprouts of uninjured tubers may be killed by heavy inoculations with *F. coeruleum*. *F. discolor sulphureum* likewise injures young sprouts if present in abundance.

Sherbakoff (59) and Pethybridge (47) have found that potato tubers rot more readily after sprouting. To determine the relative susceptibility to rot of old and new potatoes, several inoculations were made October 16, 1917, on recently harvested tubers and on tubers of the 1916 crop kept in cold storage for more than a year. The latter had sprouts only about fifteen millimeters long at the beginning of the experiment. At room temperature under a bell jar, the tubers grown in 1916 showed, October 26, about twice as large an area of rot as did those of the 1917 crop. The difference was due partly to greater shrinkage of tissue in the older potatoes. Nevertheless the newer potatoes had developed a considerable amount of rot. Additional tests with sprouted and non-sprouted tubers grown the same year indicated that while sprouted tubers usually rotted more extensively, sprouting was not at all a controlling factor in the development of the rot. In sprouted tubers there is a marked shrinkage of the tissue. Naturally infected tubers frequently rotted before the appearance of any sprouts.

Experiments to determine the effect of the fungus on tubers showing frost necrosis (Jones and Bailey, 29) as compared with healthy tubers, were made by inoculating, at the same time, both kinds of tubers. These experiments failed to show that the injury by frost had increased susceptibility to rot. Likewise, it was found that the tubers from "constitutionally degenerate" plants which had shown the so-called curly dwarf symptoms were no more susceptible to the rot caused by *F. discolor sulphureum* than were normal tubers. Indeed, the degenerate tubers often showed smaller rotted areas than did the healthy tubers.

No characteristic wilting of the foliage resulted on potato plants grown from tubers infected with *F. discolor sulphureum*. Several trials for the purpose of determining the effect of planting diseased tubers under field and greenhouse conditions gave the following results:

1. If the tuber or seed piece were badly affected at planting time, the continued rotting frequently resulted in the destruction of the sprout. Sometimes this destruction of the seed piece and the sprout ensued even when only a small amount of rot was present at planting time.

2. If the sprout were well started before the seed piece was completely rotted, it usually continued to grow, altho the resulting plant was unthrifty, owing to the loss of the reserve food in the seed piece,

and also perhaps in part to the presence of "toxic substances" (see below) in the rotting tissue in contact with the base of the sprout.

3. The rot might not develop rapidly enough to affect the sprout or growing plant. (Figures 16, 17, and 18 show examples of cases 2 and 3.)

Fusarium trichothecioides Wollenw. has been reported from St. Paul (25, 8). The writer is uncertain as to whether the tubers referred to were grown in St. Paul or collected there. At any rate, he has never isolated *F. trichothecioides* from a potato grown in Minnesota. This, of course, does not mean that it does not occur, since the whole state has not as yet been thoroly surveyed for tuber rots, but this *Fusarium* is apparently not abundant. It has been isolated several times from potatoes shipped in from western points, including one lot from North Dakota.

FUSARIUM DISEASES OF CERTAIN TRUCK CROPS

Fusarium injuries may be of considerable importance to various truck crops in the United States (71), even tho a definite wilt is not produced. Root rots and stem injuries due to *Fusaria* are rather common on several crops. Members of the Leguminosae (see 60) such as cowpea, pigeon pea, and soybean, are seriously affected.

WILT AND ROOT ROTS OF *PISUM SATIVUM*

Fusarium vasinfectum pisi was established by Van Hall (73) as the cause of St. John's disease of the garden pea. The *Fusarium* which Schikorra (60) assigned to the same species was determined by Appel and Wollenweber (2) to be identical with their species *F. falcatum*, which was reported to occur on garden peas in Germany, and on tomato fruit in Germany and the United States (76, 59). Lewis (32) isolated a *Fusarium* from diseased *Pisum sativum* in Maine, which Wollenweber determined as *F. orthoceras* App. and Wr. Wollenweber (76) also described a new species, *F. redolens*, with the following notes: "Vascular parasite, cause of wilt and foot disease of *Pisum sativum*. Distribution unknown." This author also considered that "More than one species, differing both in size of conidia and color of conidial masses, may cause the St. John's disease of the garden pea."

Little information is as yet at hand regarding the distribution or seriousness of *Fusaria* affecting the garden pea in the United States.

The first report of a serious outbreak of this disease in Minnesota came in late June, 1916, from Le Sueur. The disease caused considerable damage in a field of about 16 acres. A wilt of garden peas was reported from near Kasson in 1917.

Species of *Fusarium* have been found (4) associated with the diseased condition of roots and stems of the garden pea in Minnesota. One species, evidently belonging taxonomically in the section *Martiella* Wollenw. (76) has been found to be particularly pathogenic. The stem and root injuries resulting in wilt of the pea plants have been obtained from infecting the soil or sterilized seeds when planted in either sterilized or unsterilized soil. If considerable inoculum be applied, the seeds may rot before sprouting or shortly after (Figure 19). With a less heavy infection the plants may grow to a considerable size before the general rotting of the roots and lower stem results in wilting and death.

Studies of this disease are being made by Dr. F. R. Jones, of the United States Department of Agriculture, with whom the writer is coöperating. Cultures of the *Fusarium* have been submitted to Dr. Sherbakoff for taxonomic consideration. The writer has used this *Fusarium* in some comparative studies with other *Fusaria*, as reported later in this paper.

ROOT ROTS OF THE BEAN (*PHASEOLUS VULGARIS*)

Burkholder (7) reported *Fusarium* root rots of the bean to be serious in New York State. Reddick (55) reported that Burkholder found the fungus to be similar morphologically to *F. martii*, but different physiologically; he called the fungus *Fusarium martii phaseoli*, and described experiments indicating important relations between temperature and the development of bean plants and the "hemi parasite." Several pathologists have reported (71, p. 8) troubles from root rots due probably to *Fusarium*, from various sections of the United States.

Rots of the roots and lower stem of bean plants have been noted in Minnesota, particularly in the spring while the plants are still small and the ground cool. From such injured roots a *Fusarium* was isolated. Inoculation experiments demonstrated the pathogenicity of this fungus to bean plants. This *Fusarium* has been utilized in some temperature studies, as noted under a subsequent heading. Upon submission of the fungus to Dr. Burkholder, he pronounced it to be probably different from his *F. martii phaseoli*.

FUSARIUM DISEASES OF OTHER TRUCK CROPS IN MINNESOTA

Muskmelon wilt.—A *Fusarium* was isolated by G. R. Hoerner, of the Section of Plant Pathology, in 1916, from wilted muskmelon vines. The fungus has not been found to agree with either *F. niveum* E. F. Smith or *F. vasinfectum* Atk. (see 61, 71, 72). Inoculation experiments did not demonstrate that it was particularly parasitic to muskmelons or cucumbers. In 1918, two reports of non-bacterial wilt were

received from the region of the Twin Cities, and from one field *Fusaria* somewhat similar to the one isolated in 1916 were obtained. The trouble did not become serious in the field in 1918, and the writer considers the *Fusaria* to have been present semi-parasitically, gaining entrance when the plants were in a nonvigorous condition.

Rots of vegetables.—*Fusaria* causing rots of cucumber fruits have been isolated, and are not uncommon, affecting either green or ripe cucumbers. In view of the inoculation experiments reported later, the writer regards these *Fusaria* as acting semi-parasitically, not as specific parasites restricted to the cucumber. Lewis (32) obtained rots of cucumber fruits with several different *Fusaria*.

Wollenweber (76) has described *Fusarium sclerotium* as causing a rot of tomato fruits, and has found that *F. falcatum* also causes a rot of tomatoes. He named a fungus obtained by Lewis (32) from tomato fruits, *F. citrinum*. The writer also has isolated *Fusaria* from the tomato fruit. A wilt of tomato such as is caused by *F. lycopersici* Sacc. in the south and *F. oxysporum* and *F. orthoceras* App. and Wr. in the west (24) has not been definitely found in Minnesota.

Rots of carrot and other vegetables due to various *Fusaria* are quite common, particularly in storage and following wounds. The rots may be soft or dry. No specificity appears to exist between these fungi causing various fruit and vegetable rots and the hosts on which they may be found. This is also indicated by the inoculation experiments recorded later.

Fusarium ear rots of corn (Zea mays).—Pammel, King, and Seal (44) have summarized the literature of *Fusarium* diseases of corn. They found that roots, stalks, and ears were attacked, but the *Fusaria* isolated were not named. Sheldon (58) described *Fusarium monili-forme* as the cause of moldy corn. Hoffer and Holbert (22) have recently called attention to injury to corn plants by *Fusaria* and bacteria.

The symptoms considered by the writer have been particularly rots of the ear and cob, ordinarily pinkish or reddish in color. Such rots were widely distributed in Minnesota in 1917. As a result of early frosts that year, much immature corn was gathered.

Fusaria were isolated from field corn in the crib, but more particularly from sweet corn in the field. While inoculations have not been made to determine the pathogenicity, it was soon suggested from laboratory studies in 1917 that the *Fusarium* from some isolations from corn (both sweet and field varieties) were identical morphologically with *F. culmorum* (W. Sm.) Sacc., the wheat scab organism. Hoffer has been working upon this problem, and with others has published (23) results of cross-inoculations.

EFFECT OF TEMPERATURE ON VARIOUS FUSARIA

The relations of temperatures affecting the development of host and parasite are highly important. Considering Fusaria, the work of Humphrey (24), Link (33), Tisdale (69), Gilman (18), and others is summarized by Jones (28). The papers of Reddick (55) and of Wollenweber (76) also deal with this question.

Several of these authors have emphasized the fact that infection by the Fusarium is more serious at, or even dependent upon, a temperature near the optimum for the fungus; in the case of flax wilt, there appears to be a definite temperature below which the plant is not affected (Tisdale, l.c.). The suggestion of Reddick (l.c.) that the fungus may develop upon the host when unfavorable temperature has lowered its vitality, is important and has perhaps been partially overlooked.

Several experiments were begun in 1917 to test the relation of certain Fusaria to temperature. While the relation of the host plants to the different temperatures was not critically determined, considerable is already known in a general way.

The low temperature used in the experiment (1.1 to 1.7 degrees C.) was practically constant. The temperatures of 25, 30, and 35 degrees were fairly constant. The medium used of course strongly affects the rate of growth of the fungus. In these experiments, potato dextrose agar was employed, and since the four Fusaria were subjected in each case to the same conditions, the data are comparable at each of the different temperatures. More than one set of cultures was run at most temperatures, and from three to eight measurements were made at different periods of time. A partial series run later and not included in the table gave figures somewhat different, tho a similar relation existed between the rates of growth of the four Fusaria at each of the temperatures utilized.

Analysis of Table IV shows that the Fusarium from the bean can make a good growth at 1.1 to 1.7 degrees C., and at temperatures of 20 degrees and below grows somewhat more rapidly than does the Fusarium from pea, while at 25 degrees and above the reverse is true. The growth of each Fusarium is comparatively more favorable at the temperature more unfavorable for its host. This supplements Reddick's (55) observations. *F. oxysporum* grows well at temperatures unfavorable for the potato plant. *F. discolor sulphureum* makes but slight growth at 1.1 to 1.7 degrees, but is able to cause a slight amount of rot at this temperature (see Figure 20). At 8 to 10 degrees, this fungus rots tubers readily as shown in Figure 21.

TABLE IV
THE EFFECT OF TEMPERATURE ON THE RATE AND CHARACTER OF GROWTH OF FUSARIA

Temperature	Fusarium	Av. daily growth in radius	No. days measured	Character of mycelium	Macroconidia or sporodochia
Degrees, C. 1.1-1.7	From bean	mm. 1.4	14	Loose aerial	No sporodochia
	From pea	None	14	.....	.....
	<i>F. oxysporum</i>	None	14	.....	.....
	<i>F. discolor sulphureum</i>	Trace	14	.....	.....
8-10	From bean	2.4	13 to 20	Loose aerial	No sporodochia
	From pea	2.0	13 to 20	Close to med.	Few macroconidia
	<i>F. oxysporum</i>	1.7	13 to 20	Thickset aerial	No sporodochia
	<i>F. discolor sulphureum</i>	3.4	13 to 20	Loose aerial	No sporodochia
14-16	From bean	4.5	6 to 13	Loose aerial	No sporodochia
	From pea	4.2	6 to 13	Close to med.	No sporodochia
	<i>F. oxysporum</i>	4.5	6 to 13	Loose aerial	No sporodochia
	<i>F. discolor sulphureum</i>	6.6	6 to 13	Loose aerial	Some macroconidia
Room temperature	From bean	6.6	4 to 6	Loose aerial	No sporodochia
	From pea	9.0	4 to 6	Close to med.	Few sporodochia
	<i>F. oxysporum</i>	12.0	4 to 6	Loose aerial	Few macroconidia
	<i>F. discolor sulphureum</i>	13.0	4 to 7	Close to med.	Many sporodochia
25	From bean	6.6	4 to 6	Loose aerial	Some sporodochia
	From pea	9.0	4 to 6	Rather loose	Some sporodochia
	<i>F. oxysporum</i>	12.0	4 to 6	Loose aerial	Few sporodochia
	<i>F. discolor sulphureum</i>	13.0	4 to 6	Close to med.	Pseudopionnotes
30-31	From bean	4.7	4 to 6	Loose aerial	No sporodochia
	From pea	9.5	4 to 6	Rather loose	No sporodochia
	<i>F. oxysporum</i>	9.6	4 to 6	Rather close	Few macroconidia
	<i>F. discolor sulphureum</i>	6.0	4 to 6	Very close	Abundant pseudopionnotes
35-36	From bean	Trace	8	.....	.....
	From pea	4.3	8	Loose	No sporodochia
	<i>F. oxysporum</i>	3.2	8	Close to med.	No sporodochia
	<i>F. discolor sulphureum</i>	Trace	8	.....	.....

From about 8 to 15 degrees C., *F. discolor sulphureum* develops a loose vegetative mass of mycelium without sporodochia, whereas at about 20 degrees and above macroconidia are produced, more abundantly as the temperature rises, until at 30 degrees a dense pseudopionnotes is produced, with mycelium close to or sunken in the agar. Removal of cultures of this fungus from higher or lower temperatures to room temperature allows again the development of the growth characteristic in the new temperature. (Figures 22 and 27.) The abundant spore production of this fungus at higher temperatures has a bearing

on the accumulation of inoculum in storage houses, and perhaps fields, during the summer months.

Freezing would hardly be expected to injure *Fusaria*. Bartram (3) reported, however, that a *Fusarium* obtained from conifers succumbed to temperatures occurring in winter at Burlington, Vermont. Cultures of *F. oxysporum* exposed to the outside temperature from December 21, 1917, to February 11, 1918, began growing again when brought indoors, and transfers developed normally. This exposure not only involved at times temperatures far below freezing, but, since the cultures were placed on the south side of the building, exposure to the sun and to alternate freezing and thawing.

Similarly, cultures of *F. discolor sulphureum* were uninjured after exposure out of doors for more than a month during the winter. Wilcox, Link, and Pool (75) found that freezing did not injure *F. trichothecioides*. The frequent observation that *Fusaria*, and various other fungi as well, can overwinter in the soil shows quite clearly that low temperatures exert no serious deleterious effect upon them.

EFFECT OF MOISTURE, LIGHT, AGE, FOOD

Relations to moisture.—*Fusaria* grow readily in culture both on rather dry substances such as clover stems, and when submerged in liquid media. Possible oxygen relations involved have not been tested by the writer. That these fungi withstand dry conditions well is indicated by the fact that more than a year after inoculation test tube agar cultures of *F. oxysporum* were still viable; *F. trichothecioides* was still viable after 25 months. The tubes were exposed all this time to the dry and often warm conditions of the laboratory. Humphrey (24, p. 15) reports viability of cultures containing chlamydospores after two years' laboratory dessication in a test tube.

Light.—Cultures grow almost equally well in light or dark, altho, as frequently observed, the colors produced are much more vivid in rather bright light; sunlight on the other hand, is unfavorable.

Age.—That cultures of *Fusaria* may lose their virulence after some period of time on culture media is suggested as a possibility by Sherbakoff (59) and Link (33). The writer has not found that this necessarily holds true. Cultures of *F. oxysporum* obtained as mentioned from Wollenweber's laboratory on February 8, 1915, and which had of course been isolated some time previously, were still able to cause infection of potato stems and rot of tubers about three years later. Appel and Wollenweber (2) note that cultures were still virulent after two years; Edson and Shapovalov (15) found that age did not lessen pathogenicity. It is of course true that cultures may cease to be "high cultures" and produce fewer macroconidia if transferred,

for example, only at long periods. While such cultures may not be as actively virulent as "high cultures," a ready way sometimes to bring about a high culture is by inoculation into the proper host and by subsequent reisolation.

Food.—While the writer has not endeavored to determine specifically which enzymes are produced by certain species of *Fusarium*, he has grown these fungi on various media, both synthetic and complex; it is obvious that they are not restricted in their saprophytic development as to the food used. The work of Hawkins (21) showed that sucrase, maltase, xylanase, and diastase were secreted by both *F. oxysporum* and *F. radicicola*. He found these two fungi to have practically the same effect on the potato.

The situation with regard to the use of starch by various *Fusaria* requires special consideration. Smith and Swingle (63) noted that the starch grains in a rotted potato (causative *Fusarium* not certainly *F. oxysporum*) were not corroded, altho they found some change as evidenced by the staining reaction with iodine. Hawkins (l.c.) observed that starch was not used by the *Fusaria* with which he worked unless first gelatinized. Hawkins sought an explanation in the slowness of action or diffusibility of the enzyme. It may be noted, however, that many writers consider the outer layer of the starch grain to be not homogeneous with the interior. Shapovalov (56) translates Naumov and Pomasski as finding, however, that *F. roseum* Link and *F. subulatum* App. and Wr., which caused "intoxicating bread," dissolved starch in the seeds of cereals.

The writer has investigated the effect of *F. discolor sulphureum* on starch, with results similar to those reported by Hawkins: starch grains in a rotted potato are intact, and stain as darkly with stronger iodine solutions as grains from normal potatoes. The appearance of less blue (more purplish or reddish) staining with dilute iodine is sometimes to be noted with starch from such rotted potatoes, and is of uncertain significance. On gelatinized starch, that is, starch paste made by boiling starch with distilled water, *F. discolor sulphureum* and several other species of *Fusarium* grew fairly well and produced normal spores. It would seem, however, that, barring a possibly less ready separation from the tissue, commercial starch should be procurable from dry rotted potatoes.

To test the effect of prolonged action of fungi and bacteria causing rot of potato tubers, a number of tubers seriously affected with *F. discolor sulphureum* were placed on March 1, 1918, in a jar, and this was covered and set away to allow the continued action of the *Fusarium* as well as any other organisms present. From time to time

samples were removed for examination of the starch grains, the mass being then stirred and set aside. The last examination was made December 24, 1918, at which time, after nearly 10 months of "rotting," the mass still contained entirely normal starch grains. Whether the number was reduced can not be stated, but no grains were found showing partial erosion. The rotting of potato tubers does not necessarily affect the starch present. Edson (15a) has recently published in some detail on this point.

CROSS-INOCULATIONS

Table V shows the results of some of the cross-inoculations attempted. The data are not presented unless the lesions produced were fairly definite. The rots reported were all obtained at room temperature. The plants inoculated were kept at a greenhouse temperature of about 18 to 24 degrees C.

The evidence presented in Table V seems to indicate that various *Fusaria* may cause rot on certain fruits, such as cucumber, apple, or tomato, the host serving as hardly more than a "culture medium," in these cases, for the development of the *Fusarium*. Potato tubers may also be rotted by several species of *Fusarium*, altho it was found that with certain *Fusaria*, rot was obtained more readily after the potatoes had been dug some little time. Sprouting did not seem to be a necessary corollary. Such forms as *F. trichothecioides* and *F. discolor sulphureum*, could of course produce rot at any time. While it is evident that certain forms, including those just noted, are, under natural conditions, the chief producers of injury to potatoes, it is not apparent that any certain species of *Fusarium* causes rot on tomato, cucumber, and other vegetables.

Cross-inoculation experiments are being continued, since it is evident that the effect of *Fusaria* on different hosts is important from the standpoint of crop rotation.

TABLE V
RESULTS OF CROSS INOCULATIONS WITH FUSARIA

Fusarium	Host tried	Development	Extent of injury 3 or 4 weeks	Remarks
F. oxysporum	Orange fruit	Rot	$\frac{1}{4}$ fruit	Usually a soft rot.
	Tomato fruit	Rot	$\frac{1}{2}$ fruit	
	Potato tuber	Rot	Whole tuber	
	Potato plants	Injury	See previous data
	Cucumber fruits	Soft rot	.....
	Apple Fruit	Rot	$\frac{1}{8}$ fruit	Sterilized soil used
	Bean plants	No effect noted	.....
F. discolor sulphureum	Pea plants	Slight root injury	Abundant rot
	Cucumber fruits	Soft rot	$\frac{1}{2}$ fruit	
	Bean plants	No wilt or rot noted	.....
	Pea plants	No wilt or rot noted	Light and heavy inoculations made
	Potato plants	No "wilt"	.....
	Potato tuber	Rot, usually dry rot	See previous data
			Whole tuber	
F. trichothecioides	Orange fruit	Rather soft rot	$\frac{1}{8}$ fruit	See previous data Rind and core particularly attacked
	Lemon fruit	Rather soft rot	$\frac{1}{4}$ fruit	
	Apple fruit	Rather soft rot	$\frac{1}{2}$ fruit	
	Sweet potato	Slight rot	25mm	
	Cucumber fruit	Soft rot	$\frac{1}{2}$ fruit	
	Tomato fruit	Soft rot	$\frac{1}{2}$ fruit	
	Carrot	Dry rot	$\frac{3}{4}$ carrot	
	Year old potato tuber	Dry rot	$\frac{1}{2}$ tuber	
	Newly dug potato	Dry rot	$\frac{1}{4}$ tuber	
	Rotted potato tubers planted	No wilt	.....
F. culmorum	Apple fruit	Slight rot	30 mm	See previous data and Fig. 21
	Potato tuber	Rather soft rot	.....
	Cucumber fruit	Soft rot	$\frac{1}{4}$ fruit	
	Bean plants	No injury noted	.....
Fusarium from bean	Pea plants	No injury noted	See previous data
	Potato tuber	Rot in some cases	25-40 mm	
	Bean plant	Root rots	.....
Fusarium from pea	Pea plant	Slight root injury	Injury occasional
	Potato tuber	Rot in some cases	25-40 mm	
	Pea plant	Root rots and wilt	.....
F. lini	Bean plant	Trace root injury	
	Potato tuber	Some rot	20-40 mm	
F. lycopersici	Cucumber fruit	Rot	$\frac{1}{4}$ fruit	
	Cucumber fruit	Rot	$\frac{1}{4}$ fruit	

DOES THE SUBSTRATUM ALTER THE PATHOGENICITY OF FUSARIA?

Carpenter (8) has reported several *Fusaria* as able to produce rot in potatoes. Sherbakoff (59, p. 100) noted that "Several series of inoculations of potato tubers showed (a) that a considerable number of *Fusaria* can cause more or less rapid decay of the tubers, and (b) that most of the *Fusaria* readily produce rot only after the tubers begin to sprout." Wollenweber (76, p. 37) considered that in general the wilt parasite of one host was not found on living organs of another host, and that "the possibility of the adaptation of the parasite decreases proportionately to the taxonomic distance of the host." He states, however, that "whether such [gradual to other hosts] adaptation occurs and causes changes in the nature of the parasite, indicated in pure culture by differences in general appearance, production of color, etc., has not been determined." Sherbakoff (l. c. p. 103) noted cases of possible mutations or fluctuations and of temporary changes in morphological characters.

Sherbakoff also reported that he had isolated *F. culmorum* from rotted potato both alone and in association with other *Fusaria*. Wollenweber (l. c. p. 45) stated similarly that *F. rubiginosum* App. and Wr. (a probable synonym of *F. culmorum*) caused rot of potatoes at higher temperatures, but irregularly. The writer has isolated organisms similar morphologically to *F. culmorum* several times from rotted potatoes. In an endeavor to determine whether the morphological or physiological nature of these fungi might be altered by continued development on a host other than their characteristic habitat, inoculations were made with *F. lini*, *F. culmorum*, and the *Fusaria* mentioned above as pathogenic to peas and to beans. Some rots of potato tubers were secured with all these forms, particularly with *F. culmorum* (see Figures 23 and 24). As yet these *Fusaria* have not been noticeably changed in morphology or pathology, but experiments should be continued for a much longer time.

THE PRODUCTION OF "TOXIC SUBSTANCES" BY FUSARIA

Lutz (35) has tested the effect of used nutrient solutions, including old *Fusarium* ("*F. solani*") solutions, upon the germination and development of certain fungi. He found that such fungi produced, after a period of growth upon a medium, substances which retarded the germination or growth of fungi grown subsequently in the same medium, even tho more nutrient substances were added; other fungi produced substances acting as accelerators rather than retarders.

Sometimes both types of substances were produced by the same fungus. The effect of these substances was usually destroyed by boiling, or even by lower temperatures. He was, however, unsuccessful in certain other attempts to demonstrate an enzymatic nature of these substances. Old *Fusarium* solutions which had been boiled and exposed to the light, allowed in general a larger growth of the fungus subsequently introduced than did the unheated solutions. He found also that for some of his used solutions, filtration through a clay filter removed the accelerating or retarding substances, altho this filtration did not alter the solutions in other instances. Lutz concludes that "Die von bestimmten Pilzen produzierten wachstumshemmenden resp. fördernden Stoffwechselprodukte, welche durch Kochen zerstört werden, haben keine *spezifische Wirkung* in dem Sinne dass sie immer nur auf Keimung und Wachstum derselben Pilzspezies Einfluss hätten; sie wirken auch auf die Sporen anderer Pilze."

On Currie's (14) solution the writer grew *F. oxysporum*, *F. discolor sulphureum*, the *Fusarium* injurious to peas, *Rhizopus nigricans*, and other fungi. After the fungi grew for different periods of time, these solutions were filtered carefully through filter paper, since a clay filter may, according to Lutz, absorb the products in question. The results of preliminary germination tests made with spores of *F. oxysporum* and *F. discolor sulphureum*, agreed in general with Lutz's results, and indicated that substances were produced by these fungi which were inhibitory to the subsequent germination and early development of the two *Fusaria* in the same solution. Boiling the solutions destroyed this inhibitory action.

Coons (13) reported work showing that *F. oxysporum* produced substances filterable through a Berkefeld filter, which caused early wilting of cuttings from potato vines when immersed in the filtered solution. Lathrop (31) found aldehydes to be produced by *F. cubense* E. F. Sm. Peltier (45) determined that a *Botrytis* produced a "harmful substance" that "may be some inorganic acid other than oxalic, or it may be a toxin of some kind, which, however, is not destroyed by heating to 100 degrees C." Graves (19) found that *Rhizopus nigricans* produced substances that exerted a negatively chemotropic effect upon the fungus greater than the positive chemotropic effect of certain food materials.

The solutions mentioned above, on which the *Fusaria* and *Rhizopus* had grown in Erlenmeyer flasks closed with cotton plugs for different lengths of time, were filtered, and leaves of potato, coleus, ragweed, and other plants, all cut off under water, were introduced (Table VI).

TABLE VI
EFFECTS OF SOLUTIONS IN WHICH FUNGI HAD GROWN, ON THE WILTING OF EXCISED LEAVES

Fungus which had grown in the solution	Time of growth in solution	Treatment of solution after filtration	Plant from which leaves were taken	Approximate time before consp. wilting
				Hours
<i>F. oxysporum</i>	2 months	None	Potato	2*
<i>F. oxysporum</i>	2 months	Boiled	Potato	2
<i>F. oxysporum</i>	2 months	Diluted half with water	Potato	4
<i>F. oxysporum</i>	2 months	Diluted and boiled	Potato	4
<i>F. oxysporum</i>	2 months	None	Coleus	12
<i>F. oxysporum</i>	10 days	None	Potato	24†
<i>F. oxysporum</i>	10 days	None	Lamb's quarters	4†
<i>F. oxysporum</i>	42 days	None	Potato	7
<i>F. oxysporum</i>	42 days	Diluted half with water	Potato	8
<i>F. oxysporum</i>	42 days	Filtered through diatomaceous earth	Potato	10
<i>F. oxysporum</i>	42 days	None	Ragweed	7
<i>F. oxysporum</i>	42 days	Diluted half with water	Ragweed	7
<i>F. oxysporum</i>	42 days	Filtered through diatomaceous earth	Ragweed	8
<i>F. discolor sulphureum</i>	2 months	None	Potato	2
<i>F. discolor sulphureum</i>	2 months	Boiled	Potato	2
<i>F. discolor sulphureum</i>	42 days	None	Potato	7
<i>F. discolor sulphureum</i>	42 days	Boiled	Potato	8
<i>F. discolor sulphureum</i>	42 days	None	Ragweed	6
<i>F. discolor sulphureum</i>	42 days	Boiled	Ragweed	6
<i>Fusarium</i> from pea	2 months	None	Potato	3
<i>Fusarium</i> from pea	2 months	None	Coleus	12
<i>Fusarium</i> from pea	2 months	Diluted half with water and neutralized	Potato	4
<i>Fusarium</i> from pea	2 months	Diluted as above and boiled	Potato	4
<i>Fusarium</i> from pea	2 months	Diluted with 3 vols. water and neutralized	Potato	4
<i>Fusarium</i> from pea	2 months	Diluted as above and boiled	Potato	4
<i>Fusarium</i> from pea	42 days	None	Potato	7
<i>Fusarium</i> from pea	42 days	Made slightly alkaline	Potato	7‡
<i>Fusarium</i> from pea	42 days	Diluted with 3 vols. water	Potato	8
<i>Fusarium</i> from pea	42 days	Boiled	Potato	7
<i>Fusarium</i> from pea	42 days	None	Ragweed	4
<i>Fusarium</i> from pea	42 days	Made slightly alkaline	Ragweed	4
<i>Fusarium</i> from pea	42 days	Diluted with 3 vols. water	Ragweed	5
<i>Fusarium</i> from pea	42 days	Boiled	Ragweed	3
<i>Rhizopus nigricans</i>	2 months	None	Potato	1½
<i>Rhizopus nigricans</i>	2 months	None	Coleus	5
<i>Rhizopus nigricans</i>	42 days	None	Potato	7
<i>Rhizopus nigricans</i>	42 days	Boiled	Potato	6
<i>Rhizopus nigricans</i>	42 days	Boiled	Ragweed	6
<i>Rhizopus nigricans</i>	42 days	None	Ragweed	6
None	None	Curries, freshly made	Potato	24+
None	None	Curries, freshly made, boiled	Potato	24+
None	None	Curries, 42 days old	Potato	16
None	None	Curries, 42 days old	Ragweed	10
None	None	Curries, 42 days old, boiled	Potato	14
None	None	Curries, 42 days old, boiled	Ragweed	10
None	None	Tap or distilled water	Potato	48+
None	None	Tap or distilled water	Coleus	48+
None	None	Tap or distilled water	Ragweed	24+

* Potato leaves for tests at any one time were taken from plants of the same age and in similar condition. For the two-months-old solutions, the leaves were from full-grown potato plants.

† Tests after ten days reported in only this case, since with all the solutions it was evident that no particular development of "toxic substance" had ensued.

‡ Wilt less pronounced than in preceding case.

Tests were also run with other *Fusaria*, and with *Rhizoctonia* and *Penicillium*. Wilting of excised leaves of various plants ensued more rapidly in old solutions. Wilting occurred even after considerable dilution. It is not to be explained on the basis of acidity. It is to be noted that no specific action is evident between the fungi tried and any one plant; potato leaves wilt as readily in old *Rhizopus* solutions as in solutions in which *F. oxysporum* had grown. This is in agreement with Lutz's results in growing fungi in old solutions. A difference exists, in that boiling the solution exerts no evident effect upon the action of old solutions on the leaves. In certain cases leaves took on a crinkled, distorted, or mosaic appearance, resembling sometimes the condition obtained by Smith (62, pl. 63).

"MIXED CULTURE" RELATIONSHIPS

Nature seldom works with pure cultures. The interrelationships of various organisms forming the mixed cultures of nature have received little study (see Rahn 54, p. 181). In view of the frequency with which various bacteria may be associated with *Fusaria* in wilt diseases and tuber rots, the writer undertook tests to ascertain some relations between certain bacteria and *Fusaria*.

It is a matter of common observation that fungi belonging to the genus *Fusarium* grow vigorously on any of the common culture media. Indeed, *Fusaria* are often troublesome as saprophytes in isolation, dilution, and other cultures of various organisms, on account of the vigor and rapidity of their growth. The writer has observed *Fusaria* to grow over and "swamp" colonies of *Penicillium* and other fungi.

When, for example, two colonies of the same or of different fungi develop in a Petri dish, there is often a mutual cessation of growth at about the point where the colonies meet. Aside from the possible presence of any growth-arresting substance, there may be a lack of food, or possibly some mechanical obstruction of growth from the presence of hyphae, in the case of fungi. With a bacterial and fungous colony, however, the former should offer less mechanical impediment to the growth of the latter.

Rahn (53) and others have shown that bacteria may produce growth-arresting substances, inhibiting more especially the further growth of the same organism. Elliot (16) has emphasized the changes in the mycelial characters of some species of *Alternaria* due to contact with colonies of certain bacteria. Sherbakoff (59, p. 214 f.) found chlamydospores especially abundant when *Fusaria* grew in the presence of bacteria.

In the writer's experiments, Petri dishes of potato dextrose agar were used, inoculated at the center with the *Fusarium*, and midway on the radii with bacteria at the same time, then incubated until the colonies reached each other. In other cases the bacteria were first inoculated in the center and, since the *Fusaria* usually grow more rapidly than the bacteria, after incubation from one day to three days the *Fusaria* were inoculated on the radii. *F. oxysporum*, *F. discolor sulphureum*, and the *Fusaria* from the bean and the pea were employed. *Bacillus atrosepticus* v. Hall, obtained through the courtesy of Dr. Morse, was used, since the blackleg organism is often found in both the stems and the tubers of potatoes. *B. carotovorus* Jones, certain undetermined species of bacteria isolated from rotted potato tubers and stems, *Pseudomonas phaseoli* E. F. Sm., and some common saprophytes such as *Bacillus subtilis* (Ehr.) Cohn and *B. prodigiosus* (Ehr.) Fleug., were also employed. Figures 25 to 30, with explanations in the list of plates, show in detail characteristic results. These experiments, which were duplicated several times, showed that in general a colony of bacteria which exerted a retarding influence on one species of *Fusarium*, exerted a similar influence on the other three species. Here again no specificity of "toxic substance" for any certain species of fungus was noted. Some bacteria exerted no observed influence, some accelerated, and some retarded growth of the fungus. The production of mycelium was sometimes changed in quantity, or the color reaction upon the medium was altered. On the whole the *Fusaria* were very tolerant to the presence of bacteria. No marked alteration of the mycelium or spores was found as a result of the action of the bacterial colonies on the fungus. While the writer has no reason to doubt the authenticity or vigor of the bacterial cultures used, he has not checked this point. Table VII summarizes the observations.

TABLE VII
EFFECT OF BACTERIA ON CERTAIN FUSARIA

	<i>Bacillus atrosepticus</i>	Ps. <i>phaseoli</i>	From rotted potato stem	From rotted seed piece	<i>B. subtilis</i>
<i>F. oxysporum</i>	Slight alteration of growth; aerial mycelium marked	Retarded growth	Retarded growth	Retarded growth medium colored	No change
<i>F. discolor sulphureum</i>	No effect noted	Retarded growth	Retarded growth	Marked retardation	No change
<i>F. from bean</i>	Growth somewhat accelerated, or no change*	Retarded growth	Retarded growth	Retardation	Acceleration* or no change
<i>F. from pea</i>	No effect noted	Retarded growth	Retarded growth	.....	No change

* Acceleration of growth did not ensue in every trial. In general, however, the same results were secured in the different tests.

GENERAL DISCUSSION

In considering Fusaria and the diseases they induce, we may first consider these fungi as vigorously growing saprophytes. Their longevity in the soil is a matter of prime importance.

Bolley, in 1901 (5), showed that soil became "flax sick" because of an accumulation of *F. lini*; he stated that when once serious in the soil, "It can live from year to year upon the humus of the soil. . . . The fungus is able to live in the soil for many years without the presence of a flax crop to feed upon." Orton (40), referring to *F. oxysporum* in the San Joaquin Valley, California, stated that the fungus "may be present in nature in some of these alluvial soils" and at any rate soon accumulated sufficiently in the soil to render potato growing unprofitable. Jensen (26) reported the isolation of *F. oxysporum* from soil from the eastern part of the United States.

It is significant that Pratt (49,50,51,52) found *F. trichothecoides*, *F. radiculicola*, and apparently also *F. oxysporum*, in virgin western soils. Werkenthin (74) found in Texas "that the virgin soil contained fungi which are known to be parasitic to cultivated plants, e.g., *Fusarium Solani* (Mart). Sacc., *Fusarium oxysporum* Schlecht., and *Fusarium radiculicola* Wollenweber." These fungi he considered "true inhabitants of the soil." Taylor (68) found *Fusarium* spp. to a depth of 24 inches, in Rhode Island. Coons (13) obtained what was apparently *F. oxysporum* from native Michigan soils.

There is evidence, then, that *F. oxysporum* may be present in many soils, and may become of considerable importance as succeeding crops of potatoes are grown; it must increase greatly from its growth in roots and stems of parasitized plants, and especially from its development on the dying potato stems and their débris. Such saprophytic fungi are able to withstand various unfavorable environmental conditions and persist in the soil through the production of microconidia and macroconidia, chlamydospores, or "perennating mycelium." In their growth, some Fusaria at least are able to compete successfully with various bacteria and other organisms with which they come in contact.

While Fusaria are active saprophytes, there can be, on the other hand, no question as to their seriousness as plant parasites; their abundant saprophytic growth only renders their control in some respects more difficult. Despite their semi-parasitic nature, many Fusaria, such as *F. oxysporum*, exhibit what amounts to a considerable specificity of parasitism to certain crops. *F. oxysporum*, however, can attack any part of the potato plant; stem, stolon, root, tuber, or even leaf. If the fungus is present in abundance, it can cause a com-

plete rotting off of the stems. It is not surprising, then, that from plants showing atypical symptoms of wilt in the field, *F. oxysporum* should be isolated, especially when the soil and weather conditions are propitious. The Early Ohio variety has been found to be commonly affected, particularly in the Red River Valley. This may be correlated with the fact that the Early Ohio remains through a considerable period in late summer in a condition of slow maturity and lessened vigor.

In regard to the cause of wilting in potato plants into which *F. oxysporum* has gained entrance, a common explanation is that of mechanical vascular clogging. Link (35) considers the killing of the root system to be as important as this clogging, and Coons (13, p. 302) would add also the systemic poisoning from the production of substances by the fungus. The writer's experiments indicate that the fungus does produce toxic substances, but that various other fungi produce substances equally toxic, the only specificity being in the fact that the other fungi tried are ordinarily unable to gain entrance into the tissues of the plant. It would seem, however, that the three factors mentioned may operate together, with the addition in cases of foot rot of a considerable rotting of the underground portions of the potato plant.

The association of injury to the potato stem from *Rhizoctonia* or *Colletotrichum atromentarium* (Berk. & Br.) Taub. (67) and of *F. oxysporum* within such stems, and the occasional coincident occurrence of bacteria, *Verticillium*, or other fungi with *F. oxysporum* indicate that *Fusarium* wilt ensues more readily when the plant is weakened, and that other organisms may follow or aid the *Fusarium* in causing injury to the potato plant.

Tisdale (70) has shown that the method of infection by *F. lini* is through root hairs, stomata, or epidermis; in resistant flax the plant was enabled to cork out the perhaps weakened hyphae, which could, however, gain preliminary entrance into the plant. He found further that *F. conglomerans* could penetrate the root hairs of flax, as it normally penetrated cabbage, but in flax it did not develop far. *F. lini* could also probably penetrate the young root hairs of cabbage.

While rots of potato tubers are attainable in the laboratory with various *Fusaria*, in Minnesota the economically important *Fusarium* causing rot of tubers is, as far as the writer's evidence goes, *F. discolor sulphureum*. *F. oxysporum* may injure the tuber somewhat by development at the stem end or considerably in the vascular system, or occasionally by causing a rot; other *Fusaria* more rarely cause dry rot alone or in association with other organisms. *F. discolor sulphureum* evidently lives over especially in storage houses; the writer

has observed it in the fall growing luxuriantly, particularly on dirt floors and walls and on débris in potato houses that had held potatoes the previous year.

Infection of the tuber may sometimes apparently ensue from contamination with the organism from the field. Once this fungus gains entrance it can develop at ordinary temperatures regardless of the humidity in storage, tho lower humidity obviously lessens the liability of infection. Relatively low temperatures, particularly cold storage, (1 to 3 degrees C.) allow but slight progress of the disease.

While *F. discolor sulphureum* ordinarily gains entrance through wounds, it is worthy of note as reported above that it may sometimes evidently infect through lenticels. In this connection it may be noted that Pratt (49) found that *F. radicicola* might infect the tuber through the stem end, lenticel, or eye; Wilcox, Link, and Pool (75) and Pratt (51) found that *F. trichothecioides*, on the other hand, infected only through bruises or other injury. Experiments and observations indicate that tubers become naturally infected with *F. discolor sulphureum* principally through wounds.

Tomato, cucumber, and some other fruits and various vegetables, especially when mature, may be rotted by several Fusaria. Numerous other fungi, such as *Penicillium* spp., may also rot these plant parts; the action is hardly more than saprophytic growth upon easily available food material. While various fungi such as *Penicillium* spp., *Aspergillus* spp., *Stysanus stemonitis*, *Verticillium* sp., *Alternaria* sp., are often found on or in rotted tubers or on healthy tubers, inoculation experiments failed to show any noteworthy ability of these fungi to rot the potato. The normal tuber is not an available source of food for them. Certain Fusaria are also unable to utilize readily the potato tuber as a food supply.

CONTROL MEASURES

POTATO WILT

The methods of control ordinarily recommended are clipping the stem ends and rotation of crops. The former method, while of undoubted value in removing some infection as well as the somewhat weaker eyes near the stem end, is not effective in seriously infected soils. Whether or not *F. oxysporum* occurs naturally in Minnesota soils, it is now widely distributed in the potato growing regions. Observational evidence has failed to show that this fungus seriously attacks other crops in the state. It undoubtedly remains in some abundance in Minnesota soils for a considerable time.

It seems to the writer that the observation that the *Fusarium* causing potato wilt in Minnesota attacks the plants more especially at the time when blossoming, tuber setting, and hot weather have reduced the vigor of these plants, offers considerable hope in the development of control measures. From this standpoint the utilization of more vigorous strains of potatoes, rotation of crops, improvement of the seedbed, clean culture, and other factors tending to produce more vigorous plants likewise lessen the liability to attack by *F. oxysporum*.

The writer is uncertain as to the interpretation to place upon the data presented by Manns (36, p. 317-319) and considered as tending to show that the "fungus will average in sick fields as great a percentage in reduction under favorable conditions as under drouth." Manns evidently bases this conclusion on the fact that a three-year rotation plot at the Ohio station yielded in 1909 only 69 bushels per acre, whereas the county averaged 186 bushels per acre. It would seem, however, that throughout that county, in which the wilt had presumably been present previously (l.c., p. 311), it could not have greatly reduced the yield in 1909 despite the supposed higher percentage of seed infection in 1908 (l.c., p. 319; see also yield of spray plot, as noted below). Of course this does not explain the low yield in the rotation plot at the Ohio station in 1909.

The work of Manns with bordeaux mixture is also significant. He found that despite the fact that "the only active factor at work in 1909 in reducing the yield on the area plotted for spraying was the work of the *Fusarium* blight, which was very prevalent . . . the growth in all sprayed plots continued from one to three weeks longer than in the unsprayed," with an average yield of 170.36 bushels per acre in the unsprayed and 181.72 bushels per acre in the sprayed plots. He adds, "The writer is satisfied that spraying heavily four times during the season does somewhat retard the action of the *Fusarium* fungus. Just how the results are brought about can not be satisfactorily explained." It would seem that the explanation may lie in the increased vitality of plants which are sprayed, and which can thus resist the action of the semi-parasitic *F. oxysporum*. Stewart (66) had previously in New York State obtained a yield of 266 bushels per acre from tubers obtained from wilted vines and in which "when cut at the stem end, blackened fibers are seen penetrating the flesh to a considerable distance." This plot was sprayed thoroly eight or nine times with bordeaux mixture. While it is not certain that Stewart was dealing with *F. oxysporum* wilt, the results obtained are comparable to those secured by Manns.

The writer has obtained as yet only empirical and fragmentary evidence as to the effect of spraying upon the occurrence of wilt in Minnesota. In the northeastern states, where spraying is commonly practiced, wilt is not prevalent. It must not be forgotten, however, that in this region cool weather and other conditions are more favorable to the production of healthy and vigorous plants than in warmer regions.

The results secured in Minnesota by A. G. Tolaas and certain county agents in the use of seed-plot methods, including selection, treatment, rotation, and good cultural conditions, indicate that wilt may be lessened by methods which tend to add vigor to the plants. A. G. Newhall, in 1918, found a case in point: A field in Cass County, a portion of which had received some care, had 15 per cent of wilt, whereas in another portion in which negligence had allowed weeds to develop and the potato plants to become less thrifty, 30 per cent of wilt occurred.

Removal of débris from a field that had grown potatoes would lessen considerably the amount of culture medium for the *Fusarium*. The consideration involved as to fungi in returning such débris to the field after a period of rotting, is undetermined.

POTATO DRY ROT

Control measures that may be used against the rot caused by *F. discolor sulphureum* have not been found to be different from those recommended by various writers against other fusarial dry rots. Highly important is more careful handling of potatoes during and after digging to avoid cuts, bruises, and injuries, since the fungus attacks the tubers ordinarily and most easily through wounds. Storage cold enough to prevent absolutely the development of this rot is hardly attainable in any storage facilities possessed by the average grower, except possibly in the use of pits in the field. Considerably less infection would probably result, however, if the storage rooms were thoroly disinfected before potatoes were put in, and cleaned out carefully after the potatoes were removed. A disinfection of the tubers before storage would probably be commercially profitable, at least in the case of seed potatoes.

Control measures against root rots of truck crops are indicated in the rotation of crops and the most favorable growing conditions for the crop. Careful handling and clean cool storage of fruits and vegetables subject to *Fusarium* rots will reduce the injury.

SUMMARY

1. *Fusarium oxysporum* Schl. is the cause of one of the most serious diseases of the potato plant in Minnesota.

2. This fungus characteristically produces the symptoms known as wilt. It attacks the roots and lower stem of the potato plant, particularly during the blossoming and tuber setting periods, when the weather is likely to be unfavorable to the potato, tho not to the fungus. *F. oxysporum* can moreover attack any part of the potato plant, and under certain conditions, particularly in wet soil, causes darkening and rotting of the stem and other symptoms not typical of wilt. It may rot the seed tuber under field conditions.

3. As a saprophyte, *F. oxysporum* grows vigorously on the affected potato plants, accumulates in considerable abundance in the soil throughout the season, and persists for some time. In the fall it may attack plants which have previously produced a normal crop of tubers.

4. The strains of *F. oxysporum* used were not, under ordinary conditions, sufficiently active parasites to cause infection of younger potato plants from artificial inoculations of the soil or seed tuber. At higher temperatures, symptoms of disease may occur. If the soil is inoculated heavily, rotting of the seed tuber and of the sprout or stem may result.

5. Wilted plants do not necessarily result from planting seed tubers from affected plants. While such "seed" is less satisfactory than tubers produced under healthy vines, other measures in addition to seed selection or clipping off the stem ends are necessary to avoid wilt.

6. While *F. oxysporum* is largely confined to the potato in Minnesota, its habits are for the most part hemi-parasitic.

7. The danger of serious infection by the wilt *Fusarium* is lessened by measures tending to add to the vigor of the plants, particularly during the latter part of the season.

8. *Fusarium discolor sulphureum* is the common cause of storage dry rot of potato tubers in Minnesota.

9. This fungus gains entrance commonly through wounds, tho the rot may sometimes be induced by applying the fungus to the uninjured surface of the tuber.

10. Tubers from normal potato vines rot as readily as those from "constitutionally degenerate" plants, and as readily as tubers showing frost necrosis. None of the varieties of potatoes tested was found to be resistant to this tuber dry rot.

11. Rot may develop on unsprouted tubers, and under dry conditions. Very slight rot may develop even at temperatures below 2 degrees C.

12. At temperatures below about 16 degrees C., *F. discolor sulphureum* produces more abundant aerial mycelium; at temperatures of from 20 to 30 degrees C., a dense pseudopionnotes.

13. The starch grains in the tubers affected with dry rot are not appreciably affected.

14. *F. discolor sulphureum* does not naturally cause a wilt of potato plants, but infected seed tubers may produce less vigorous sprouts, or even no sprouts.

15. While other Fusaria, such as *F. oxysporum* and *F. culmorum* may cause rot of potato tubers, such rots have been found to be of little economic importance in storage.

16. Careful handling of tubers and the maintenance of clean cold storage conditions, are important prophylactic measures against the storage rot caused by *F. discolor sulphureum*.

17. Fusarium root rots of *Pisum sativum* and of *Phaseolus vulgaris* are of importance in Minnesota.

18. Ear rots of *Zea mays* due to Fusaria, probably including *F. culmorum*, are common in the state.

19. Cross-inoculations indicate that wilt or root rot producing Fusaria may exhibit a selective tendency in their more common occurrence on certain species of host plants, altho hemi-parasitic in that their action may be more distinctly influenced by conditions unfavorable to the host.

20. A temperature at which the host develops poorly may allow an active development of the attacking Fusarium.

21. Isolations and cross-inoculations demonstrate that no single species of Fusarium is chiefly responsible for the common storage rots of vegetables and of cucumber and tomato fruits.

22. Fusaria produced substances in old solutions that inhibited the germination of spores of the same or other fungi. After boiling, such old solutions allowed normal germination.

23. Substances detrimental to such plants as potato, coleus, and ragweed, as shown by the wilting of excised leaves when placed in solutions, were also produced by Fusaria and other fungi in cultures. This injurious effect persisted after boiling, neutralization, or some dilution of the solutions. Specific fungi did not produce substances selectively injurious to any one or more plants.

24. Fusaria are, in general, little influenced by bacteria, tho some bacteria may influence the rate of growth of Fusaria.

25. The Fusaria examined could withstand considerable dessication, exposure to low temperatures or to alternate freezing and thawing, and can utilize a wide variety of food substances. Altho important parasites, Fusaria are efficient saprophytes.

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EXPLANATION OF PLATES

- Figure 1. Plant showing typical wilting. Illustration by the courtesy of H. A. Edson of the United States Department of Agriculture. Taken in a field in Clay County, Minnesota, August 11, 1917.
- Figure 2. Rather early stage of wilting. Taken by Dr. Edson, also in Clay County, August 11, 1917.
- Figure 3. Plants collected August 23, 1918, from Clay County, illustrating the browning and rotting of the lower stems and of the roots. One plant also injured by stalk borer. Isolations yielded *Fusarium oxysporum* from these and similar plants.
- Figure 4. Plants showing similar and serious injury from foot rot, collected August 22 and 23, 1918, from Polk and Clay counties. The large plant illustrates also the external production of fungus after having been in a damp place about two days.
- Figure 5. Tubers from plants showing foot rot, collected in Polk County, August 22, 1918. *F. oxysporum* and secondary fungi and bacteria present, causing a rather soft rot of the tubers. This rot was not ordinarily foul smelling. The blackening shows some tendency to follow the fibro-vascular bundles.
- Figure 6. Seed piece inoculated with *F. oxysporum*, received February 8, 1915, from W. A. Orton. (No. 3394 from Wollenweber's laboratory.) Inoculation September, 1917. The seed piece had rotted, the fungus was present in the stem. Reisolations yielded *F. oxysporum*.
- Figure 7. Cage heated by carbon electric lamps to secure higher temperature.
- Figure 8. Results of rather heavy inoculation of sterilized soil with *F. oxysporum* in the warmed cage. Seed piece rotted, one stem rotted off, other injured at the base. March, 1918.
- Figure 9. A case similar to Figure 8. Stems rotted off or seriously injured at the base. March, 1918.
- Figure 10. On the left, plant growing in the warm chamber in sterilized soil infected with *F. oxysporum*. Moist conditions did not allow a serious wilting, but the plant is affected, particularly as indicated by the upper leaves. On the right, check grown from the same seed in sterilized soil. February, 1918.
- Figure 11. Affected plant growing in artificially infected soil. The lower leaves have fallen and the plant is unthrifty. February, 1918.
- Figure 12. Surface view of tubers affected with *F. discolor sulphureum* from Beardsley. The wounds from which infection occurred can be seen on the surface. January, 1918.
- Figure 13. Longitudinal sections of the tubers shown in Figure 12. The rotted tissue is dark brown or blackish, containing some "pockets" filled with mycelium and sporodochia of the fungus.
- Figure 14. Stem and eye end infection of tubers from Clay County and characteristic of the rather early stage of a considerable infection in that region. Received December 10, 1917.

Figure 15. Effect of injury, moisture, and temperature on the development of rot by *F. discolor sulphureum*. Figures A to E, inclusive, no injury to the surface; inoculum applied to the uninjured epidermis. Figures F, G, and H, slight injury to the surface before inoculation. Figures I to L, considerable wounding of surface previous to inoculation. Figures A and B, room temperature, damp. Figures C and D, room temperature, in a dessicator. Figure E, icebox (8 to 10 degrees C.), damp. Figure F, room temperature, damp. Figure G, room temperature, dessicator. Figure H, icebox, damp. Figure I, room temperature, damp. Figure J, room temperature, dessicator. Figure K, room temperature and room humidity. Figure L, icebox, damp.

Figure 16. Weak plant secured from planting seed partially rotted with *F. discolor sulphureum*. March, 1918.

Figure 17. Healthy plant from seed tuber planted at same time as that of plant shown in Figure 16. Some rot on seed when planted. The rot did not, however, progress much. March, 1918.

Figure 18. At left, base of plant shown in Figure 16, seed rotted; center, base of plant shown in Figure 17, seed healthy at insertion of stem. At right, another plant similar to the one on the left. March, 1918.

Figure 19. Pea seeds rotted and roots and lower stems of young plants affected with *Fusarium* isolated from pea plants. Greenhouse inoculations, September, 1917.

Figure 20. Four tubers at left show slight rot, with *F. discolor sulphureum* developed at 1.1 to 1.7 degrees C. Plugs cut out of potatoes in inoculating. The browned vascular ring in some of these tubers is due to frost necrosis, which had developed prior to the subjection to cold storage. Previous experiments demonstrated that this slight necrosis had no influence on the rate of rotting. At the right, a tuber almost wholly rotted when placed in cold storage. The rot progressed little at the temperature mentioned. This tuber was cut before being put in cold storage and shows the development of some mycelium on the cut surface. Duration of experiment, 31 days, March 16 to April 16, 1918.

Figure 21. Rot of potatoes from *F. discolor sulphureum* at 8 to 10 degrees C., artificial inoculation, two weeks' development.

Figure 22. *F. discolor sulphureum*: center of plate, mycelium produced at 8 to 10 degrees C.; area of less abundant mycelium produced at room temperature, containing many small sporodochia not shown clearly; circumference, mycelium produced again at 8 to 10 degrees C.

Figure 23. At the right, tuber rot secured at 25 degrees C. with *F. culmorum* from wheat; at left, rot by same fungus at room temperature (about 18 to 20 degrees C.). Time, two weeks.

Figure 24. Rot started by *F. lini* on potato tuber. Time, two weeks.

Figure 25. *F. oxysporum* inoculated January 25, 1918, in the center. The stained area (dark red in natural color) shows the area occupied by a colony of bacteria obtained originally from a rotted seed piece and as yet unidentified, over which the fungus grew slowly, as indicated by the lines marking dates. Opposite this a colony of *Bacillus atrosepticus* was present, but exerted no influence on growth or production of color. A colony of *Aspergillus* at the margin opposite the stained area checked the growth of the *Fusarium*. View from lower face of Petri dish.

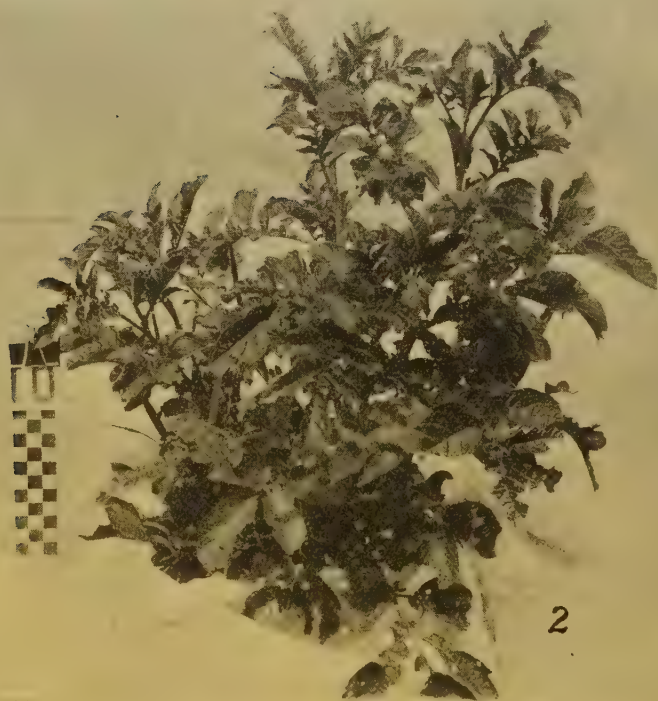
Figure 26. View from above, showing mycelium of *F. oxysporum* growing over a colony of *B. subtilis*: aerial mycelium marks the margin; no pause in the growth. The radii, etc., on the opposite side are due possibly to shrinkage of the medium.

Figure 27. *F. discolor sulphureum* retarded by a colony of bacteria (the same species of bacteria mentioned for Figure 25, obtained from a rotted seed tuber). The fungus eventually grew completely over this colony; the conidia and mycelium produced thereon appeared normal microscopically. Opposite, a colony of *Bacillus atrosepticus* had exerted no influence upon the growth. This figure illustrates the ample macroconidial production at room temperature. View from above.

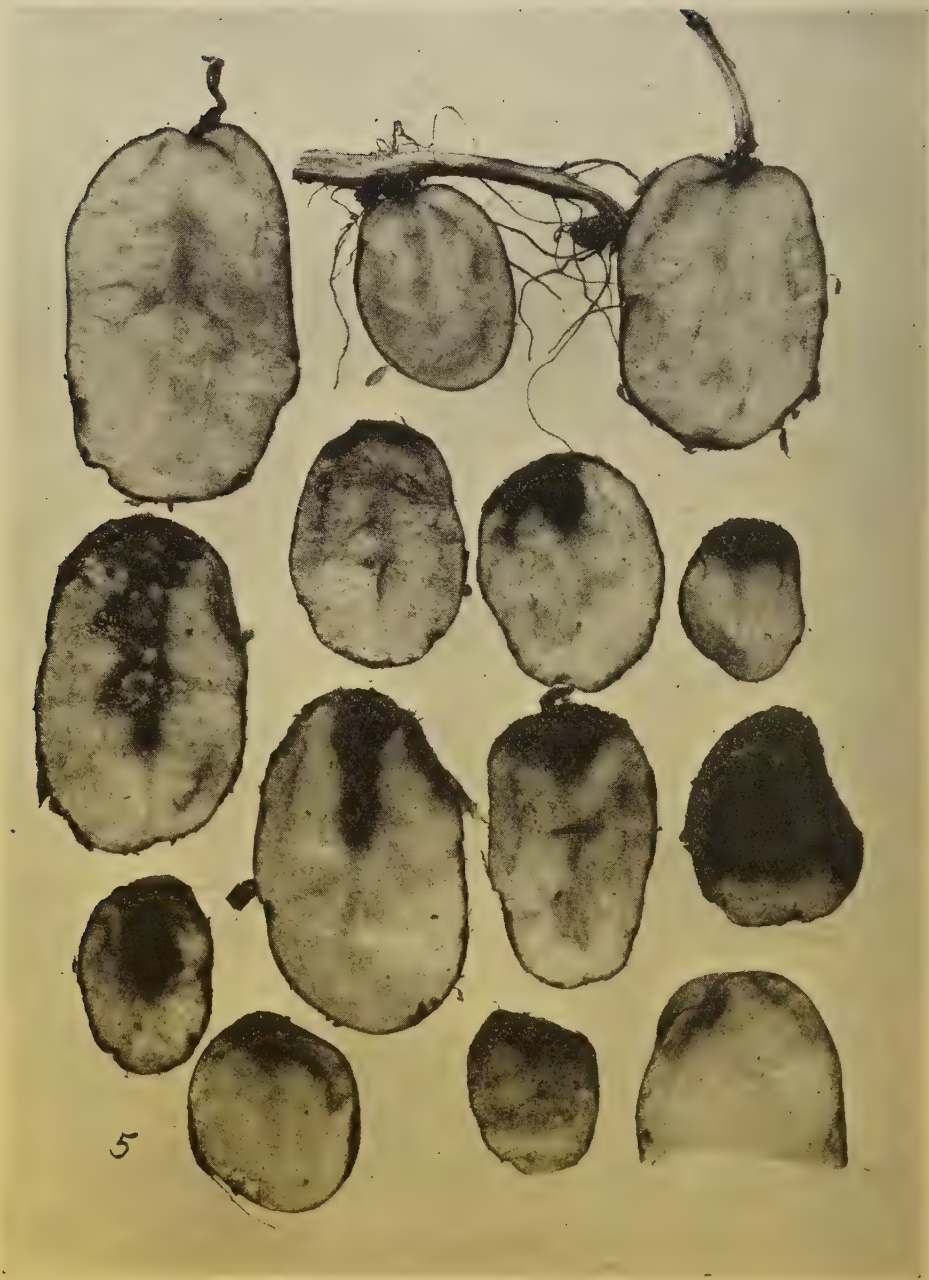
Figure 28. Fusarium from bean plant. The irregular bacterial colony, checking growth somewhat, is *Pseudomonas phaseoli*. (The fungus finally grew entirely over this colony, but more slowly.) Opposite roundish colony is *B. subtilis*. The growth of the colony was noticeably accelerated when this colony was reached, just as the growth has been accelerated on the lower side, where the fungus has pushed out over a colony of *B. atrosepticus*. "Growth arresting and accelerating" substances are evidently produced. The organisms shown in Figures 25 to 28 grew on potato dextrose agar under a bell jar at room temperature. Inoculations January 25, 1918, photographs February 5, 1918.

Figure 29. At right, relation between bacteria from a soft-rotted potato and (1) *F. oxysporum*, (2) *F. discolor sulphureum*, (3) Fusarium from pea, (4) Fusarium from bean. Bacteria inoculated in center November 9, 1918, fungi inoculations November 12, photograph November 15. The growth of the fungi was somewhat retarded, and the bacteria tended to grow between the fungous colonies. At left, *B. atrosepticus* in center. Fusaria numbered as at right, inoculations and photographs same date.

Figure 30. At right, *B. subtilis* in center, exerting little influence on the Fusaria. At left, a colony of bacteria isolated from a potato stem has diffused substances through the medium checking equally the growth of the four Fusaria. Reciprocally, the bacterial colony ceased to enlarge. Inoculations in both plates: bacteria, November 9, 1918. Fusaria, November 14, photograph November 25.

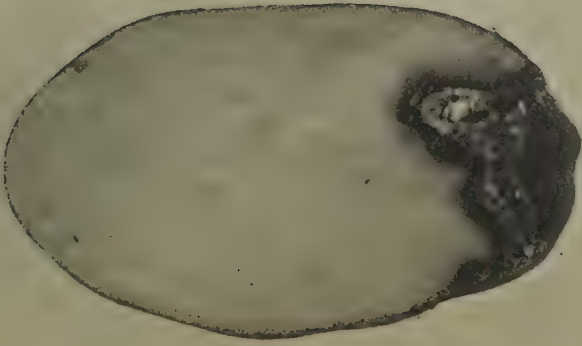




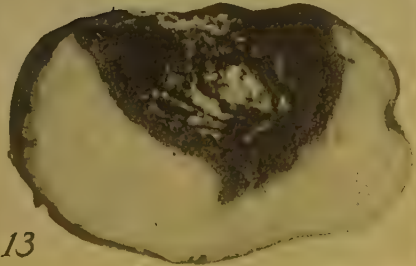
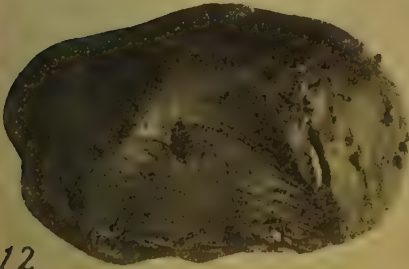
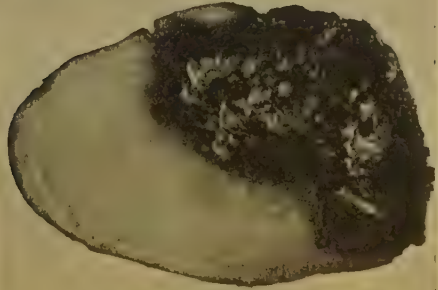
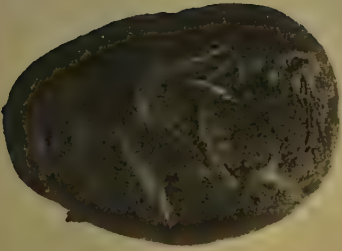






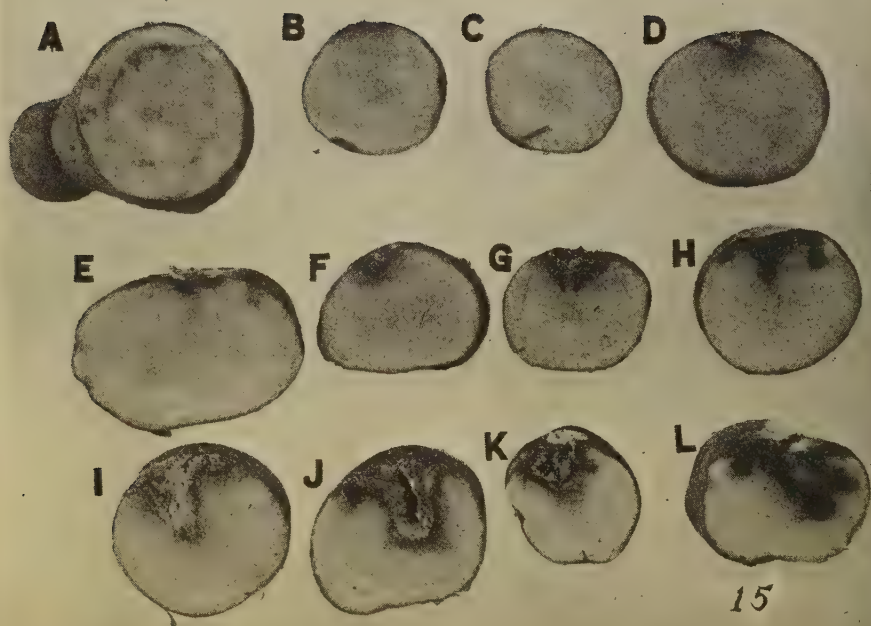


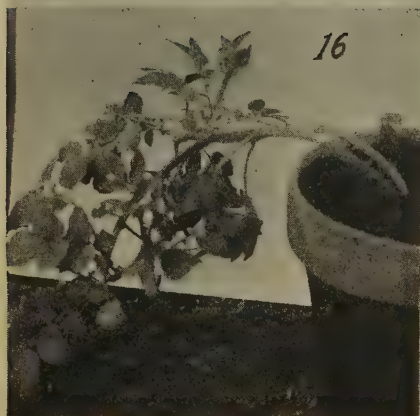
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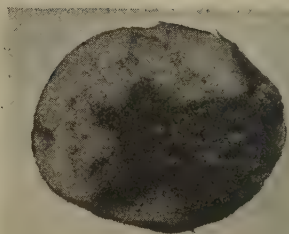
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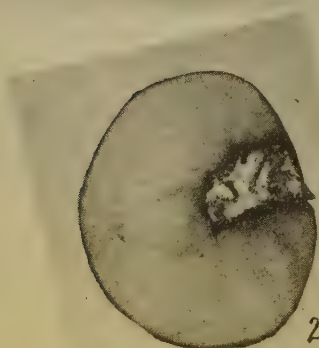




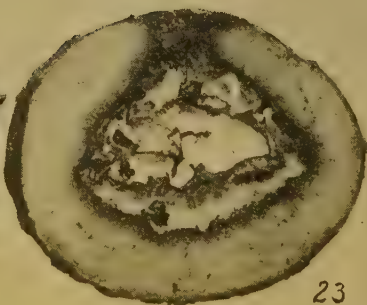
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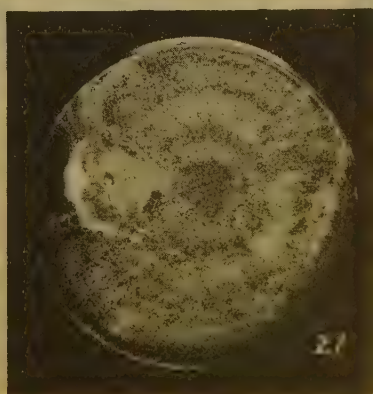
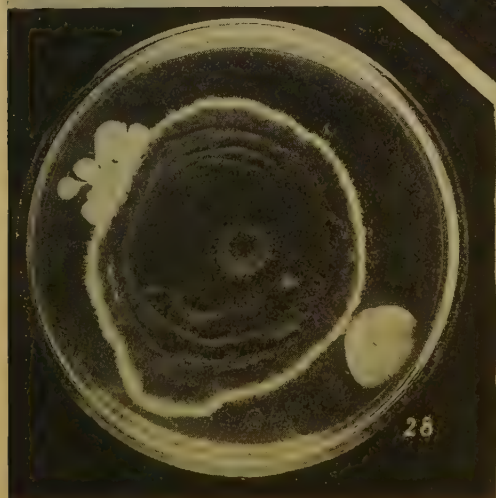
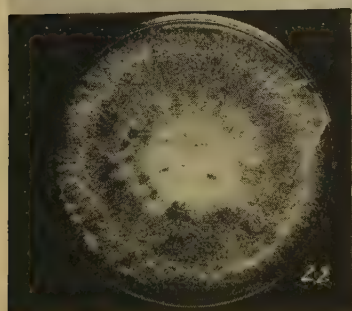
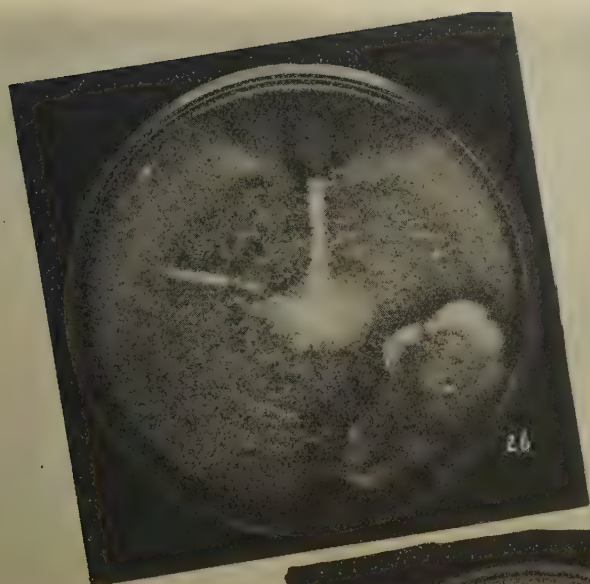
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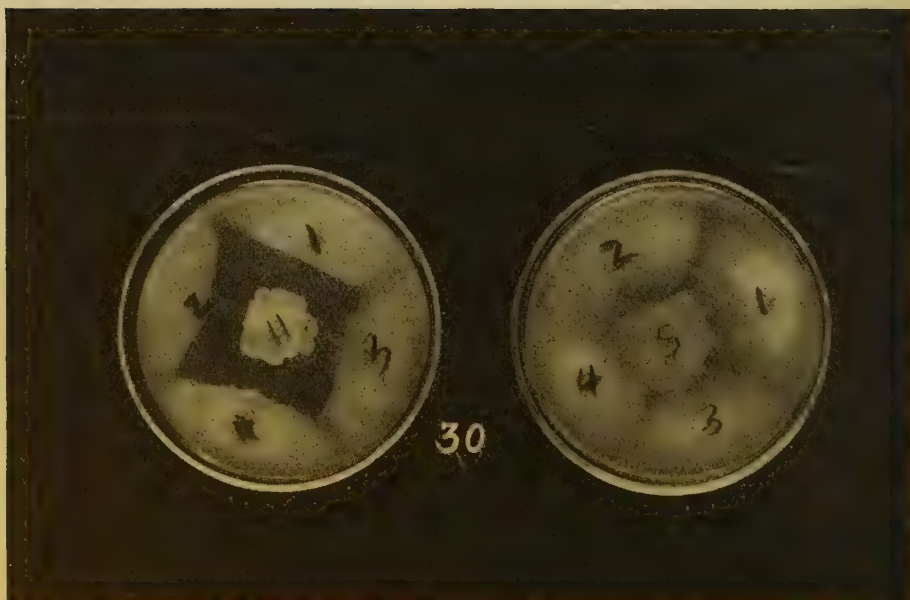


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STUDIES ON FUSARIUM DISEASES OF
POTATOES AND TRUCK CROPS
IN MINNESOTA

A THESIS SUBMITTED TO THE FACULTY
OF
THE GRADUATE SCHOOL
OF
THE UNIVERSITY OF MINNESOTA

BY

G. R. BISBY

IN PARTIAL FULFILMENT OF THE REQUIREMENTS
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STUDIES ON FUSARIUM DISEASES OF POTATOES AND TRUCK CROPS IN MINNESOTA

By G. R. BISBY

INTRODUCTION

Fusarium wilt was reported (72) as causing a loss of more than twenty-five million bushels, or 4.54 per cent of the potato crop of the United States in 1917. Despite the large damage due to *Phytophthora infestans* in this country the same year, the total loss reported from Fusarium wilt was greater. Besides the injury from wilt, Fusarium tuber rots in the field, in storage, and during transportation may destroy from 10 to 50 per cent of the crop (37, 43, 72, 75).

Minnesota is one of the states in which typical Fusarium wilt has been serious. Certain symptoms atypical of wilt have also been under observation for some time, particularly in the Red River Valley. The study of this rather anomalous disease has received particular attention. Fusarium dry rot was also found to present, in Minnesota, certain phases not emphasized heretofore. The writer has also studied certain Fusarium diseases of other truck crops as well as those of the potato.

The genus *Fusarium* was established by Link in 1809 (34). Various changes in the use of generic and specific names for the fungi in question were made during the succeeding century; the species added were often imperfectly described, and the host or substratum served frequently as the chief distinguishing diagnostic character. Smith and Swingle in 1904 (63) were forced to revert to the oldest available name to designate the Fusarium on potato, viz., *F. oxysporum* Schlechtendal, 1824. Appel and Wollenweber in 1910 (2) published a monograph of the genus *Fusarium*, and were able accurately to define several species. The literature to the year 1910 is also summarized. Wollenweber (76), Lewis (32), Sherbakoff (59), and others have also worked intensively on the Fusarium problem and described several new species. The name *Fusarium oxysporum* is, however, still applied to the fungus commonly causing wilt of potatoes.

MATERIALS AND METHODS

Isolations were made during the summers of 1916, 1917, and 1918 from potato plants showing various wilt symptoms. The plants were obtained from sections of Minnesota north of St. Paul, particularly

the Red River Valley region. Several cultures of *Fusaria* isolated in 1914 and 1915 were furnished by A. G. Tolaas. During the winters, isolations were also made from rotted potato tubers. Isolations were made from garden beans and peas, sweet corn, cucurbits, and tomatoes. Several hundred cultures were studied and numerous inoculations were made in the laboratory, in the greenhouse, and in the field in 1917 and 1918.

Various culture media were used, particularly rice and potato plugs, sweet clover stems, the common agars for dilutions, and 5 and 10 per cent dextrose agar for color reactions. The ordinary methods of technique were used unless otherwise stated.

The writer wishes to express his thanks particularly to Dr. E. C. Stakman and Dr. E. M. Freeman, under whom the work was done, for suggestions and supervision. The writer is also indebted to A. G. Tolaas and Dr. W. A. Orton for cultures and other help, and to Dr. C. D. Sherbakoff for tentative corroboration of some determinations. The writer is particularly grateful to Dr. H. A. Edson of the United States Department of Agriculture who in his visits to Minnesota has freely given information and ideas.

The writer has submitted cultures of the various unidentified *Fusaria* to Dr. Sherbakoff for such taxonomic disposition as he sees fit.

POTATO WILT

HISTORICAL

Smith and Swingle (63) made the first detailed study of the wilt of potato caused by *Fusarium oxysporum*. The dry rot of tubers discussed by them is now generally considered to be caused chiefly by other species of *Fusarium*. They described in detail the effects of the wilt fungus on the plant and its entrance into and spread within the tuber. They studied the behavior of the fungus on various media. Control methods for wilt were suggested. While the earlier publication of Stewart (65) on "Another stem blight of potato" deals with a disease similar to wilt, Stewart (66) decided in 1898 that the blight was not communicable and "not caused by any vegetable organism," and recently stated, in letters dated Nov. 18 and 30, 1918, "While the symptoms point to *Fusarium* wilt, I doubt that it was actually that disease." However, "If it is true that tubers showing pronounced discoloration of the fibro-vascular bundles, owing to the infection with *Fusarium* wilt, do not usually produce affected plants, then there is some reason for believing that my Long Island stem-blight was in reality *Fusarium* wilt. The tubers which were planted in my experiments were all very definitely affected by the stem-end browning.

Every piece planted showed the stem-end browning. Accordingly, it seems to me that more diseased plants should have resulted." Clinton's description in 1895 (11) of a "Bundle blackening of tubers" may have been of the ring discoloration caused by *F. oxysporum*. He wrote in a letter dated Dec. 3, 1918, "While the tubers mentioned may quite likely have been connected with such a wilt, I have no positive information that they were."

Orton in 1909 (40) reported that the accumulation of *F. oxysporum* and other fungi in the peat soils of sections of California soon made the growing of potatoes unprofitable. Manns (36), as a result of his work, recommended clipping the stem ends of infected tubers. This is now a commonly used control method. Orton in 1914 (42), in comparing wilt due to *F. oxysporum* with leaf roll and other diseases, considered that wilt was "apparently a disease of warmer climates," altho he recognized that "in Minnesota wilt appears to be present in the older communities."

Discussing the occurrence of this disease in Europe, Appel (1, p. 143) states, "The [wilt] disease occurs in Germany also, but is of much less importance." Nicholls (38) reported the presence of *F. oxysporum* in Tasmania, and Carpenter (10) found this fungus in potato vines and tubers in Hawaii. Reports of *F. oxysporum* from other countries are doubtful, since this name has been loosely used.

Jones (27) found potato wilt especially in the older communities in Wisconsin. Milbrath (37) noted its seriousness in North Dakota, and its importance in Minnesota has been recognized for some time by Stakman and Tolaas (64). Kohler (30) may have referred to the stem end browning caused by *F. oxysporum*, tho it may be inferred that dry rot of tubers was also involved in the rot he attributed to "an undetermined species of *Fusarium*."

Carpenter (8), Link (33), and others have shown that *F. oxysporum* can produce a rot of potatoes. This is not in agreement with Wollenweber's (76) conclusion that members of the *Elegans* section of the genus *Fusarium* cause wilt but not rot. *F. eumartii* Carpenter, belonging to the section *Martiella* (76, p. 30), has been found by Haskell (20) and C. R. Orton (39) to cause a stem rot and wilt of potato plants, as well as a rot of the tubers. "Potato wilt" may, therefore, be due to more than one species of *Fusarium*, possibly following certain geographical limits. Orton (42) reported the symptoms of *Verticillium* wilt to be similar to those of *Fusarium* wilt and stated that the distribution of the former was restricted more particularly to the northern states. *Verticillium* wilt is reported (72) to be especially serious in Oregon. Appel (1) has noted (referring presumably particularly to Minnesota) symptoms atypical of the common potato wilt.

SYMPTOMOLOGY OF POTATO WILT CONDITIONS IN MINNESOTA

The symptoms have been fully described by other writers, and in general agree with those found under Minnesota conditions. Coons (13) recently noted that in Michigan the disease may exhibit two aspects; one, a rapid wilting in which the vine dies when the tubers are about half grown; and another characterized by the dying of the plants "at the close of the growing season." He found these symptoms to depend perhaps on whether the infection is from the seed piece or from the soil.

Figures 1 and 2 show the wilt symptoms common in Minnesota fields. Except in more severe cases, the plants do not begin to wilt until about blossoming time or later. The symptoms on the upper part of the plants are apparently those resulting from a considerable reduction in water supply. A cross-section of the lower stem reveals the browning of the vascular system and often of the other tissues as well. This browning may extend to the tips of the plants, tho the bundles are often free from hyphae in these upper discolored areas. The roots are usually affected seriously. The tubers, which have ordinarily had an opportunity to develop considerably before the wilting of the plant stops their growth, may be affected at the stem end, as fully described in the literature.

Atypical wilt symptoms such as those mentioned by Appel (1, p. 147) have received particular attention. Other observers had noticed these atypical symptoms, particularly in 1914 and 1915 in the Red River Valley, and had considered that they might be caused by the blackleg organism or some species of *Fusarium*. For convenience the term "foot rot" will be used to indicate the condition in question. The writer found some of this disease in 1916, practically none in 1917, but in August, 1918, it was found in Polk and Clay counties in the form more characteristic of that seen by Appel, Edson, Stakman, Orton, and others in 1914 and 1915.

Plants affected with foot rot are shown in Figures 3, 4, and 5. There is a dark brown or almost black discoloration of the lower and underground portions of the stem. These discolored areas are often rotted. When secondary organisms are present there may be a typical soft rot. While the symptoms resemble those of blackleg somewhat, there is not the inky black, slimy rot characteristic of blackleg. The disease is, however, confused with blackleg by growers and others.

There is a more abundant development of hyphae in the primary vessels and other tissues of the stem than in stems affected with ordinary wilt. The effect on the roots and stolons is similar to that on portions of the lower stem (see Figure 5). The stem end of the

tuber may be attacked, and the way paved for invasion by secondary rotting organisms. The above-ground portions of the plant successively wilt, die, and eventually collapse. Fortunately this foot rot occurs more particularly late in the season, as is also ordinarily the case with wilt in Minnesota, so that a considerable crop of tubers may already have been produced. These tubers are, however, liable to suffer considerable injury before or during storage from the invasion of *Fusaria* and other organisms through the injured point of attachment of the tubers to the affected stolons.

The relation of this foot rot in Clay County, Minnesota, to the weather (United States Weather Record, Moorhead Station) during the 5 years this condition has been under observation is shown in Table I.

TABLE I
RELATION OF WEATHER TO THE DEVELOPMENT OF FOOT ROT

Year	Precipitation				Average temperature				Notes on the disease
	May	June	July	August	May	June	July	August	
	Inches	Inches	Inches	Inches	Degrees	Degrees	Degrees	Degrees	
1914	1.47	8.92	3.65	2.89	57.4	64.8	73.1	65.0	Abundant
1915	3.93	9.13	2.22	1.05	51.7	59.2	65.2	65.2	Present
1916	3.76	4.28	5.30	2.87	53.0	60.3	75.9	67.2	Present
1917	0.38	1.52	0.81	0.77	53.6	61.3	75.2	66.4	Absent
1918	2.73	1.79	2.68	4.90	55.0	64.4	67.7	69.4	Present late in season
Normal	2.95	4.13	3.74	3.10	54.8	64.14	68.7	65.9	

More than double the normal precipitation occurred in June, in 1914 and 1915. The rainfall was especially heavy in July, 1916. The season of 1917 was very dry, while in 1918 it was dry until late July and early August, when there was considerable precipitation. Moderately high temperature is also undoubtedly a factor in producing *Fusarium* wilt, altho, as shown by the temperature in July, 1917, the atypical foot rot does not occur as a result of high temperature without abundant rainfall; and as indicated in 1915, these symptoms may appear in a year of high precipitation even with temperatures considerably below normal. Observations indicate further that foot rot attacks the plants seriously only later in the season, even tho weather conditions from planting time on have been favorable to its development. Kohler (30) described *Fusarium* diseases of potato in Minnesota, and the foot rot condition may have been involved. He stated that "This disease does great havoc in wet years." Poor yields were obtained from planting tubers showing rot.

ETIOLOGY OF WILT OF POTATO IN MINNESOTA

The fungi isolated from various parts of wilted plants, particularly the interior of the stem near the surface of the soil, from several regions in Minnesota, especially the Red River Valley, were predominantly *Fusaria*. *Verticillium* was obtained in only a very few cases, and then in association with other organisms, indicating that it was only saprophytically or accidentally present. There was no evidence that *Verticillium* wilt is important in Minnesota. Most frequently the cultures obtained were determinable as *Fusarium oxysporum* by the character of their conidia, the salmon to lilac color of the medium (potato or rice), the dark bluish green sclerotia, and the buff sporodochia. As was to be expected, contaminations were sometimes present, and other *Fusaria* than *F. oxysporum* developed occasionally. Sometimes the difficulty in obtaining a "high culture" (Appel and Wollenweber 2, p. 22) of the *Fusarium* rendered identification somewhat less certain, owing to the paucity of macroconidia produced, or to the suppression of some other distinguishing character. The cultures were, however, run along with authentic *F. oxysporum* obtained originally from Wollenweber's laboratory (Nos. 3315 and 3394) through the courtesy of Dr. W. A. Orton. Specimens were also submitted to Dr. C. D. Sherbakoff for identification.

Ordinary wilt of potato in Minnesota appears, then, to be due, at least predominantly, to *Fusarium oxysporum*. This fungus has also been isolated several times from tubers showing brown ring discoloration. It was thus obtained from tubers grown as far north as Kittson County, in the extreme northwestern corner of the state.

ETIOLOGY OF FOOT ROT

Isolations were made from numerous wilted plants showing atypical wilt symptoms in the expectation that organisms other than *F. oxysporum* were the causal agents. Some isolations obtained by A. G. Tolaas from atypically affected plants in 1914 and 1915 were identified by the writer. The fungus obtained from plants showing foot rot symptoms was found in the majority of cases to be *F. oxysporum* and, as already indicated, the unusual appearance is attributed particularly to the heavier precipitation resulting in a watersoaked condition of the soil. This is most likely to occur in a heavy soil such as that in the Red River Valley. Other fungi and several bacteria were also isolated, but all the evidence indicated that they were merely saprophytes.

OCCURRENCE OF *FUSARIUM OXYSPORUM* IN POTATO PLANTS

In the course of development of the wilt or foot rot disease, considerable amounts of the infecting fungus are of course accumulated in the tissues of the potato stems, roots, stolons, and even in the tubers.

The following observations indicate that the fungus may grow on other parts of the plant also, and develop in greater abundance on those parts mentioned.

On vines affected with wilt in the field and placed two or more days in a moist place, a luxuriant growth of fungus may develop. (See Figure 4.) From the surface and the interior of these vines, *F. oxysporum* was isolated. Not infrequently the mycelium and spores of *F. oxysporum* may have developed abundantly in the somewhat hollow areas within the stem of plants affected in the field. Plants affected with wilt or foot rot may thus cause heavy contamination of the soil.

Isolations were made on September 10, 1917, to determine if *F. oxysporum* might be present more or less saprophytically in the stems of plants late in the season. This was shortly after a frost had practically destroyed the leaves. These plants had been grown at University Farm, part of them from northern grown seed, had not shown signs of wilt, and had produced a good crop of healthy tubers. Below the surface of the soil the inside of these stems was browned, and from some such stems "high cultures" of *F. oxysporum* were readily obtained. Similar isolations were made later in 1917, and several on October 1 and 2, 1918. The isolations made in 1918 were from the old stems of normal plants which had been killed by frost. They were taken from a field in Hennepin County which had been sprayed with bordeaux mixture, and which had yielded 214 bushels per acre. *F. oxysporum* was obtained consistently from this material.

The "dry stem rot" of potatoes with which *Rhizoctonia* is associated is common in Minnesota. That *Fusarium oxysporum* may occasionally be a factor in causing this condition is indicated by the fact that it was isolated from the external stem lesions of plants affected with "stem rot," as well as from the interior of such stems. The interior of potato stems affected with dry stem rot is often browned, especially near the base. Edson and Shapovalov (15) have shown recently that various fungi, including *F. oxysporum*, may cause stem lesions. *Rhizoctonia* hyphae may of course be present even if they are not the primary cause of the lesions.

The seed piece under the growing plant is often rotted. If the rot is caused by bacteria it is soft and foul smelling. Species of *Fusarium* may cause a dry rot. The rot of the seed piece may be soft and without a foul odor. Isolations were made in the season of 1917 from several such cases as the last two. The specimens were obtained from University Farm and other parts of the state. *F. oxysporum* was often obtained from seed tubers affected with soft rot. From tubers affected with dry rot, *F. discolor sulphureum* (Schl.) App.

and *Wr.* and other *Fusaria* were obtained. Bacteria and other fungi were of course commonly present as secondary organisms. No difficulty was experienced in securing a more or less soft rot of potato tubers with *F. oxysporum* by artificial inoculation.

Considerable mycelium of *F. oxysporum* may occur in and on the leaves of plants growing under moist conditions, even when the lower stem does not show the presence of the fungus. Such leaf infection may presumably result from inoculum carried by insects or spattered by rain. Milbrath (37) reports that leaves may be affected, altho he may have meant only internally. (See also 15.) Cases of external as well as internal infection of leaves and petioles have been secured from artificial infection in the greenhouse.

The relation of *F. oxysporum* to the soil is discussed in another section.

ARTIFICIAL INOCULATIONS WITH *F. OXYSPORUM* ON POTATO PLANTS

Many preliminary experiments in the greenhouse and in the field to secure infection and wilt of potato plants by artificially inoculating *F. oxysporum* into the seed piece planted, or into the soil, were unsuccessful. An examination of the literature indicates also that other workers have not had great success in securing infection of potato plants with the wilt organism under ordinary conditions. It is evident that *F. oxysporum* is not vigorously parasitic to actively growing potato plants.

Sometimes such results as shown in Figure 6 were obtained under greenhouse conditions. Rotting of the seed piece, browning of the stem, and death of the leaves ensued from inoculating the seed tuber with *F. oxysporum*. This is hardly characteristic of *Fusarium* wilt, however, tho resembling the foot rot condition.

In view of the possibility that the average temperature in the greenhouse during the winter months was not sufficiently high for good infection, the cage shown in Figure 7 was constructed, and heated with two carbon electric light bulbs. A soil temperature of from 20 to 30 degrees could thus be maintained. The humidity was of course also high. Figures 8 and 9 show a type of injury resulting from inoculating sterilized soil heavily with *F. oxysporum* under these warm and damp conditions. This injury was caused several times with *F. oxysporum*, and *F. radicola* Wollenw. caused a similar injury in one trial. Fitch and Bennett (17) illustrate a somewhat similar condition as found in the field. Link (33) also secured stem rots in the laboratory with *F. oxysporum*. Injuries such as are illustrated

in Figures 8 and 9 are considered entirely comparable with the naturally occurring foot rot condition illustrated in Figures 3 and 4.

Figures 10 and 11 show two infected plants resulting from a lighter infection of the soil, and are believed to represent a fair greenhouse manifestation of *Fusarium* wilt. It is to be noted that the upper leaves show the characteristic rolling (see 1, p. 143). The higher temperatures in the warm chamber, while allowing infection, were unfavorable to the potato. Plants placed inside the chamber died sooner than corresponding plants left outside.

FIELD STUDIES WITH SEED TUBERS FROM WILTED PLANTS

Wilted plants do not result from planting infected seed, unless conditions are favorable to the development of the fungus. These conditions, particularly a high temperature, are often at the same time unfavorable to the potato. Seed from vines wilted in the field, showing more or less of the bundle blackening, usually produced plants in the greenhouse similar to those from normal seed. Such seed planted in the field in 1917 in not seriously infected soil gave no more wilt than several plots from ordinary seed.

A fairly extensive study of the effect of planting tubers produced under wilted vines was made in the field in 1918. Late in the summer of 1917 several Green Mountain potatoes were dug by hand from under badly wilted vines in Clay County, Minnesota. There was no marked amount of stem end discoloration of the tubers at digging time, nor did this vascular browning increase appreciably through the winter. Through the courtesy of Dr. G. H. Coons, a half bushel of tubers was obtained in the spring of 1918 from a field in Michigan which had shown from 30 to 40 per cent of wilt. Plantings were made in the field at University Farm. The tubers from Clay County were planted whole, and those from Michigan were divided into two lots. Several isolations were made from one lot to determine the fungi present in the browned vascular tissue of the stem end of the tubers. *F. oxysporum* and various other *Fusaria* were obtained. The other lot was used for planting, and the tubers were sorted into two groups according to size. The smaller tubers were halved to give eye and stem ends, and the larger tubers were cut longitudinally through the former point of attachment of the stolon, then cut transversely, to give two each of approximately equal eye ends and stem ends. These were planted in two places on University Farm. The stand of the potatoes obtained from Michigan was poor, owing particularly to frost necrosis of the tubers (29) and to the fact that the "seed" had been obtained from seriously affected plants. It was also necessary to plant the tubers rather late in the spring. The seed pieces were planted 16½ inches apart in rows 3 feet apart.

The average yield of the tubers from Clay County was slightly more than one pound per hill ($29\frac{1}{2}$ pounds from 25 hills) or at the rate of 180 bushels per acre. The plants were not wilted. The yield indicates that the seed was not affected; indeed, it is possible that the greater immaturity of such seed resulted in added vigor of the progeny.

The results with the seed from Michigan are summarized in Table II.

TABLE II
RESULT OF PLANTING TUBERS FROM BADLY WILTED VINES

Character of seed piece	Date planted	Area of plot*	No. of wilted plants	Yield	Rate per acre
		Sq. Ft.		Pounds	Bushels
Eye quarters	June 4	268.5	0	32.0	86.5
Stem quarters	June 4	268.5	2	23.0	62.2
Eye halves	June 4	148.5	2	12.0	58.4
Stem halves	June 4	148.5	1	14.5	70.9

* Including proper marginal area about plot.

In 1918 a plot of the eight standard varieties (6) was planted, and a considerable amount of fungus from cultures of *F. oxysporum* introduced into the soil beside each seed piece at planting time. Here again only healthy plants were produced, indicating that none of the varieties is particularly susceptible to the fungus, unless other factors are conducive to the development of wilt.

The data presented in Table II indicate that serious disease does not necessarily follow from planting seed from wilted vines, and that no more wilt may result from the use of the stem ends than from the use of eye ends. Other observations support this view. Wilted plants do not, of course, produce tubers of as good quality as healthy plants, and it can not be denied that infected tubers may introduce more of the disease into the soil. Such seed is considerably less desirable than seed from healthy plants, and plants affected with wilt should be rogued from plots to be dug for seed. Selecting seed or clipping the stem ends is, however, not alone sufficient to avoid loss from wilt. The considerations involved in the use of affected seed from the north for planting in the southern states require further attention.

FUSARIUM DRY ROT OF POTATO TUBERS

HISTORICAL

Some of the earlier literature regarding Fusarium rots of potato, both American and European, is summarized by Smith and Swingle (63) and in part by Manns (36), altho these authors did not distinguish between the *Fusaria* causing dry rot and those causing wilt.

The monograph by Appel and Wollenweber (2) made it possible to distinguish between species of *Fusaria*. Jamieson and Wollenweber (25) reported *F. coeruleum* (Lib.) Sacc. and *F. discolor sulphureum* to occur in Germany as wound parasites, and the American *F. trichothecioides* Wollenw. was described and reported from Washington, Minnesota, Iowa, Nebraska, and South Dakota. Inoculation studies were described. *F. tuberivorum* Wilcox and Link (75) was considered a synonym of the previously established *F. trichothecioides*. Orton (41) in 1913 gave a brief description of this "powdery dry rot" and suggested methods of control. Wollenweber (76) distinguished sharply between wilt- and rot-producing *Fusaria*. Carpenter (8), besides showing that this sharp distinction did not hold for tuber rots, described *F. eumartii* as a new species of *Fusarium* causing dry and wet rot of tubers. He also reported *F. radiculicola* as producing tuber rot through wound infection. Pratt (49, 51, 52) showed that *F. radiculicola* and *F. trichothecioides* were apparently well distributed through the western desert soils, and suggested disinfecting the stock before storage or the use of cold storage, as a control measure against rot. Link (33) has shown that *F. trichothecioides* can cause wilt as well as rot, and also that *F. oxysporum* can cause rot as well as wilt. Sherbakoff (59) stated that the *Fusarium* most commonly producing potato rot in the eastern United States is *F. coeruleum*. Pethybridge (46, 47, 48), in Ireland, performed experiments with dry rot of potatoes which he considered due to *F. coeruleum*. Orton (39) and Haskell (20) have found that *F. eumartii* can cause, besides a tuber rot, a wilt or stem rot of the potato plant. Milbrath (37) reported dry rot to be serious in North Dakota, causing a loss of "over 20 per cent in all storehouses in the Northwest" in 1914. Altho he did not specify which *Fusarium* was responsible, it is noteworthy that Carpenter mentions having isolated *F. discolor sulphureum* from tubers sent in by Milbrath, as well as from tubers obtained from South Dakota. Other references to *F. discolor sulphureum* (2, 25, 59, 76) mention its presence in Germany, and nowhere has the writer seen it referred to as being serious in the United States.

DISTRIBUTION

In the United States, *Fusarium* dry rots appear to be widely distributed east and west, but the north central part of the country has not been very critically surveyed. In Minnesota, isolations have been made from tubers grown in Kittson, Pennington, Polk, Norman, Mahanomen, Clay, Wilkin, Otter Tail, Bigstone, Swift, and Lincoln counties, along the western side of Minnesota, and from Brookings County,

South Dakota. Some have also been made from the region of the Twin Cities and from Crow Wing and Kanabec counties.

SYMPTOMOLOGY

The *Fusarium* dry rot of potatoes found in Minnesota is a brown, compact, firm rot, without the foul odor of bacterial rots. Cavities are often present in the tissues. These cavities and the tissues contain considerable mycelium which develops readily and abundantly when the tuber is placed in a damp chamber. From the edges of the rotted areas, pure cultures of the fungus may usually be obtained directly from tissue cultures. The skin of the potato is often wrinkled. Figures 12, 13, and 14 show the appearance of this rot as found in storage. The rot starts at any point on the potato, and in the case of stored potatoes usually from a wound. It is more abundant as the winter advances. It does not have the powdery appearance characteristic of the rot caused by *F. trichothecioides*, because the spore masses when present are more compact and less dry.

Sections of rotted potato show that the fungus grows through the cells in considerable abundance. The observation of Orton (39) and Pratt (49) that a dry rot fungus has a tendency to follow the vascular system can be confirmed in tubers rotted by *F. discolor sulphureum*. The writer's experience in general corroborates Carpenter's observations (8) that there is no real distinction between the effects of *Fusaria* causing dry and soft rots, altho *F. discolor sulphureum* under ordinary conditions produces a dry rot.

ETIOLOGY

F. discolor sulphureum was obtained readily from affected tubers grown in many parts of Minnesota. Altho the fact that this *Fusarium* is the cause of a dry rot of potatoes has not been emphasized, it is one of the most common causes of rot in Minnesota, particularly in the Red River Valley. The ability of this fungus to cause dry rot has been demonstrated frequently.

EXPERIMENTAL

Efforts to determine varietal differences in susceptibility were unsuccessful. The eight standard varieties for Minnesota (Brown and Wellington, 6) were used, and rot developed from wound inoculations in each variety.

A series of experiments was made to determine the relations of injury to the tuber and of moisture and temperature to the development of the rot caused by *F. discolor sulphureum*. Tubers were inoculated on the uninjured epidermis, on the surface after slight wounding with

a sterile scalpel, and in deeper cuts into the tuber. Sets of inoculated tubers were kept at different temperatures under damp conditions, and similar sets in dessicators containing calcium chloride. The results are summarized in Table III. (See Figure 15.) The extent and rapidity of the rot is proportional to the seriousness of the injury to the tuber, tho the fungus may sometimes enter through uninjured surfaces, probably through lenticels. The later series of inoculations (December, 1918), incubated for 13 days (see Table III), resulted in less infection than in the previous experiments. A less vigorous "strain" of the *Fusarium* may have been used. There are characteristic differences in the rot developed at different temperatures. Under cooler conditions, the tissues are darkened and contain few "pockets" and few spores. It is evident that the fungus can rot tubers readily under dry conditions, especially if it gains entrance through wounds. The absence of wounds appears to retard the development of *F. discolor sulphureum* more than dryness or storage temperature, except in the case of cold storage.

TABLE III

EFFECT OF INJURY, TEMPERATURE, AND MOISTURE UPON THE OCCURRENCE OF THE ROT OF POTATOES CAUSED BY *F. discolor sulphureum*

Character of injury	Moisture	Temperature	Tubers inoculated	Time	Results
		Degrees		Days	
None	Saturated	1.1-1.7	4	30	No rot
	Saturated	8-10	4	12	No rot
	Saturated	8-10	9	13	No rot
	Dessicator	8-10	4	12	Slight rot in some cases
	Dessicator	8-10	8	13	No rot
	Saturated	Room	4	12	Slight rot in some cases
	Saturated	Room	8	13	No rot
	Dessicator	Room	6	12	Slight rot in some cases
	Room humidity	Room	4	12	Slight rot in some cases
	Saturated	25	6	13	No rot
Slight	Dessicator	25	6	13	No rot
	Saturated	1.1-1.7	4	30	Trace rot
	Saturated	8-10	4	12	Moderate rot on all
	Saturated	8-10	9	13	Slight rot on 3 tubers
	Dessicator	8-10	4	12	Moderate rot on all
	Dessicator	8-10	8	13	Slight rot on 4 tubers
	Dessicator	Room	6	12	Moderate rot on 4 tubers
	Saturated	Room	4	12	Moderate rot on all
	Saturated	Room	8	13	Slight rot on 2 tubers
	Saturated	25	6	13	Slight rot on 2 tubers
Considerable	Dessicator	25	6	13	Slight rot on 3 tubers
	Saturated	1.1-1.7	8	30	Slight rot
	Saturated	8-10	6	12	Much rot on all
	Dessicator	8-10	6	12	Moderate rot on all
	Dessicator	Room	4	12	Much rot on all
	Saturated	Room	4	12	Much rot on all
	Room humidity	Room	4	12	Much rot on all
	Saturated	25	5	12	Much rot

Pethybridge (47) has reported that young sprouts of uninjured tubers may be killed by heavy inoculations with *F. coeruleum*. *F. discolor sulphureum* likewise injures young sprouts if present in abundance.

Sherbakoff (59) and Pethybridge (47) have found that potato tubers rot more readily after sprouting. To determine the relative susceptibility to rot of old and new potatoes, several inoculations were made October 16, 1917, on recently harvested tubers and on tubers of the 1916 crop kept in cold storage for more than a year. The latter had sprouts only about fifteen millimeters long at the beginning of the experiment. At room temperature under a bell jar, the tubers grown in 1916 showed, October 26, about twice as large an area of rot as did those of the 1917 crop. The difference was due partly to greater shrinkage of tissue in the older potatoes. Nevertheless the newer potatoes had developed a considerable amount of rot. Additional tests with sprouted and non-sprouted tubers grown the same year indicated that while sprouted tubers usually rotted more extensively, sprouting was not at all a controlling factor in the development of the rot. In sprouted tubers there is a marked shrinkage of the tissue. Naturally infected tubers frequently rotted before the appearance of any sprouts.

Experiments to determine the effect of the fungus on tubers showing frost necrosis (Jones and Bailey, 29) as compared with healthy tubers, were made by inoculating, at the same time, both kinds of tubers. These experiments failed to show that the injury by frost had increased susceptibility to rot. Likewise, it was found that the tubers from "constitutionally degenerate" plants which had shown the so-called curly dwarf symptoms were no more susceptible to the rot caused by *F. discolor sulphureum* than were normal tubers. Indeed, the degenerate tubers often showed smaller rotted areas than did the healthy tubers.

No characteristic wilting of the foliage resulted on potato plants grown from tubers infected with *F. discolor sulphureum*. Several trials for the purpose of determining the effect of planting diseased tubers under field and greenhouse conditions gave the following results:

1. If the tuber or seed piece were badly affected at planting time, the continued rotting frequently resulted in the destruction of the sprout. Sometimes this destruction of the seed piece and the sprout ensued even when only a small amount of rot was present at planting time.

2. If the sprout were well started before the seed piece was completely rotted, it usually continued to grow, altho the resulting plant was unthrifty, owing to the loss of the reserve food in the seed piece,

and also perhaps in part to the presence of "toxic substances" (see below) in the rotting tissue in contact with the base of the sprout.

3. The rot might not develop rapidly enough to affect the sprout or growing plant. (Figures 16, 17, and 18 show examples of cases 2 and 3.)

Fusarium trichothecioides Wollenw. has been reported from St. Paul (25, 8). The writer is uncertain as to whether the tubers referred to were grown in St. Paul or collected there. At any rate, he has never isolated *F. trichothecioides* from a potato grown in Minnesota. This, of course, does not mean that it does not occur, since the whole state has not as yet been thoroly surveyed for tuber rots, but this *Fusarium* is apparently not abundant. It has been isolated several times from potatoes shipped in from western points, including one lot from North Dakota.

FUSARIUM DISEASES OF CERTAIN TRUCK CROPS

Fusarium injuries may be of considerable importance to various truck crops in the United States (71), even tho a definite wilt is not produced. Root rots and stem injuries due to *Fusaria* are rather common on several crops. Members of the Leguminosae (see 60) such as cowpea, pigeon pea, and soybean, are seriously affected.

WILT AND ROOT ROTS OF *PISUM SATIVUM*

Fusarium vasinfectum pisi was established by Van Hall (73) as the cause of St. John's disease of the garden pea. The *Fusarium* which Schikorra (60) assigned to the same species was determined by Appel and Wollenweber (2) to be identical with their species *F. falcatum*, which was reported to occur on garden peas in Germany, and on tomato fruit in Germany and the United States (76, 59). Lewis (32) isolated a *Fusarium* from diseased *Pisum sativum* in Maine, which Wollenweber determined as *F. orthoceras* App. and Wr. Wollenweber (76) also described a new species, *F. redolens*, with the following notes: "Vascular parasite, cause of wilt and foot disease of *Pisum sativum*. Distribution unknown." This author also considered that "More than one species, differing both in size of conidia and color of conidial masses, may cause the St. John's disease of the garden pea."

Little information is as yet at hand regarding the distribution or seriousness of *Fusaria* affecting the garden pea in the United States.

The first report of a serious outbreak of this disease in Minnesota came in late June, 1916, from Le Sueur. The disease caused considerable damage in a field of about 16 acres. A wilt of garden peas was reported from near Kasson in 1917.

Species of *Fusarium* have been found (4) associated with the diseased condition of roots and stems of the garden pea in Minnesota. One species, evidently belonging taxonomically in the section *Martiella* Wollenw. (76) has been found to be particularly pathogenic. The stem and root injuries resulting in wilt of the pea plants have been obtained from infecting the soil or sterilized seeds when planted in either sterilized or unsterilized soil. If considerable inoculum be applied, the seeds may rot before sprouting or shortly after (Figure 19). With a less heavy infection the plants may grow to a considerable size before the general rotting of the roots and lower stem results in wilting and death.

Studies of this disease are being made by Dr. F. R. Jones, of the United States Department of Agriculture, with whom the writer is coöperating. Cultures of the *Fusarium* have been submitted to Dr. Sherbakoff for taxonomic consideration. The writer has used this *Fusarium* in some comparative studies with other *Fusaria*, as reported later in this paper.

ROOT ROTS OF THE BEAN (*PHASEOLUS VULGARIS*)

Burkholder (7) reported *Fusarium* root rots of the bean to be serious in New York State. Reddick (55) reported that Burkholder found the fungus to be similar morphologically to *F. martii*, but different physiologically; he called the fungus *Fusarium martii phaseoli*, and described experiments indicating important relations between temperature and the development of bean plants and the "hemi parasite." Several pathologists have reported (71, p. 8) troubles from root rots due probably to *Fusarium*, from various sections of the United States.

Rots of the roots and lower stem of bean plants have been noted in Minnesota, particularly in the spring while the plants are still small and the ground cool. From such injured roots a *Fusarium* was isolated. Inoculation experiments demonstrated the pathogenicity of this fungus to bean plants. This *Fusarium* has been utilized in some temperature studies, as noted under a subsequent heading. Upon submission of the fungus to Dr. Burkholder, he pronounced it to be probably different from his *F. martii phaseoli*.

FUSARIUM DISEASES OF OTHER TRUCK CROPS IN MINNESOTA

Muskmelon wilt.—A *Fusarium* was isolated by G. R. Hoerner, of the Section of Plant Pathology, in 1916, from wilted muskmelon vines. The fungus has not been found to agree with either *F. niveum* E. F. Smith or *F. vasinfectum* Atk. (see 61, 71, 72). Inoculation experiments did not demonstrate that it was particularly parasitic to muskmelons or cucumbers. In 1918, two reports of non-bacterial wilt were

received from the region of the Twin Cities, and from one field *Fusaria* somewhat similar to the one isolated in 1916 were obtained. The trouble did not become serious in the field in 1918, and the writer considers the *Fusaria* to have been present semi-parasitically, gaining entrance when the plants were in a nonvigorous condition.

Rots of vegetables.—*Fusaria* causing rots of cucumber fruits have been isolated, and are not uncommon, affecting either green or ripe cucumbers. In view of the inoculation experiments reported later, the writer regards these *Fusaria* as acting semi-parasitically, not as specific parasites restricted to the cucumber. Lewis (32) obtained rots of cucumber fruits with several different *Fusaria*.

Wollenweber (76) has described *Fusarium sclerotium* as causing a rot of tomato fruits, and has found that *F. falcatum* also causes a rot of tomatoes. He named a fungus obtained by Lewis (32) from tomato fruits, *F. citrinum*. The writer also has isolated *Fusaria* from the tomato fruit. A wilt of tomato such as is caused by *F. lycopersici* Sacc. in the south and *F. oxysporum* and *F. orthoceras* App. and Wr. in the west (24) has not been definitely found in Minnesota.

Rots of carrot and other vegetables due to various *Fusaria* are quite common, particularly in storage and following wounds. The rots may be soft or dry. No specificity appears to exist between these fungi causing various fruit and vegetable rots and the hosts on which they may be found. This is also indicated by the inoculation experiments recorded later.

Fusarium ear rots of corn (Zea mays).—Pammel, King, and Seal (44) have summarized the literature of *Fusarium* diseases of corn. They found that roots, stalks, and ears were attacked, but the *Fusaria* isolated were not named. Sheldon (58) described *Fusarium moniliforme* as the cause of moldy corn. Hoffer and Holbert (22) have recently called attention to injury to corn plants by *Fusaria* and bacteria.

The symptoms considered by the writer have been particularly rots of the ear and cob, ordinarily pinkish or reddish in color. Such rots were widely distributed in Minnesota in 1917. As a result of early frosts that year, much immature corn was gathered.

Fusaria were isolated from field corn in the crib, but more particularly from sweet corn in the field. While inoculations have not been made to determine the pathogenicity, it was soon suggested from laboratory studies in 1917 that the *Fusarium* from some isolations from corn (both sweet and field varieties) were identical morphologically with *F. culmorum* (W. Sm.) Sacc., the wheat scab organism. Hoffer has been working upon this problem, and with others has published (23) results of cross-inoculations.

EFFECT OF TEMPERATURE ON VARIOUS FUSARIA

The relations of temperatures affecting the development of host and parasite are highly important. Considering Fusaria, the work of Humphrey (24), Link (33), Tisdale (69), Gilman (18), and others is summarized by Jones (28). The papers of Reddick (55) and of Wollenweber (76) also deal with this question.

Several of these authors have emphasized the fact that infection by the Fusarium is more serious at, or even dependent upon, a temperature near the optimum for the fungus; in the case of flax wilt, there appears to be a definite temperature below which the plant is not affected (Tisdale, l.c.). The suggestion of Reddick (l.c.) that the fungus may develop upon the host when unfavorable temperature has lowered its vitality, is important and has perhaps been partially overlooked.

Several experiments were begun in 1917 to test the relation of certain Fusaria to temperature. While the relation of the host plants to the different temperatures was not critically determined, considerable is already known in a general way.

The low temperature used in the experiment (1.1 to 1.7 degrees C.) was practically constant. The temperatures of 25, 30, and 35 degrees were fairly constant. The medium used of course strongly affects the rate of growth of the fungus. In these experiments, potato dextrose agar was employed, and since the four Fusaria were subjected in each case to the same conditions, the data are comparable at each of the different temperatures. More than one set of cultures was run at most temperatures, and from three to eight measurements were made at different periods of time. A partial series run later and not included in the table gave figures somewhat different, though a similar relation existed between the rates of growth of the four Fusaria at each of the temperatures utilized.

Analysis of Table IV shows that the Fusarium from the bean can make a good growth at 1.1 to 1.7 degrees C., and at temperatures of 20 degrees and below grows somewhat more rapidly than does the Fusarium from pea, while at 25 degrees and above the reverse is true. The growth of each Fusarium is comparatively more favorable at the temperature more unfavorable for its host. This supplements Reddick's (55) observations. *F. oxysporum* grows well at temperatures unfavorable for the potato plant. *F. discolor sulphureum* makes but slight growth at 1.1 to 1.7 degrees, but is able to cause a slight amount of rot at this temperature (see Figure 20). At 8 to 10 degrees, this fungus rots tubers readily as shown in Figure 21.

TABLE IV

THE EFFECT OF TEMPERATURE ON THE RATE AND CHARACTER OF GROWTH OF FUSARIA

Temperature	Fusarium	Av. daily growth in radius	No. days measured	Character of mycelium	Macroconidia or sporodochia
Degrees, C. 1.1-1.7	From bean	mm. 1.4	14	Loose aerial	No sporodochia
	From pea	None	14	.....	.....
	<i>F. oxysporum</i>	None	14	.....	.....
	<i>F. discolor sulphureum</i>	Trace	14	.....	.....
8-10	From bean	2.4	13 to 20	Loose aerial	No sporodochia
	From pea	2.0	13 to 20	Close to med.	Few macroconidia
	<i>F. oxysporum</i>	1.7	13 to 20	Thickset aerial	No sporodochia
	<i>F. discolor sulphureum</i>	3.4	13 to 20	Loose aerial	No sporodochia
14-16	From bean	4.5	6 to 13	Loose aerial	No sporodochia
	From pea	4.2	6 to 13	Loose to med.	No sporodochia
	<i>F. oxysporum</i>	4.5	6 to 13	Loose aerial	No sporodochia
	<i>F. discolor sulphureum</i>	6.6	6 to 13	Loose aerial	Some macroconidia
Room temperature	From bean	6.6	4 to 6	Loose aerial	No sporodochia
	From pea	9.0	4 to 6	Close to med.	Few sporodochia
	<i>F. oxysporum</i>	12.0	4 to 6	Loose aerial	Few macroconidia
	<i>F. discolor sulphureum</i>	13.0	4 to 7	Close to med.	Many sporodochia
25	From bean	6.6	4 to 6	Loose aerial	Some sporodochia
	From pea	9.0	4 to 6	Rather loose	Some sporodochia
	<i>F. oxysporum</i>	12.0	4 to 6	Loose aerial	Few sporodochia
	<i>F. discolor sulphureum</i>	13.0	4 to 6	Close to med.	Pseudopionnotes
30-31	From bean	4.7	4 to 6	Loose aerial	No sporodochia
	From pea	9.5	4 to 6	Rather loose	No sporodochia
	<i>F. oxysporum</i>	9.6	4 to 6	Rather close	Few macroconidia
	<i>F. discolor sulphureum</i>	6.0	4 to 6	Very close	Abundant pseudopionnotes
35-36	From bean	Trace	8	.....	.....
	From pea	4.3	8	Loose	No sporodochia
	<i>F. oxysporum</i>	3.2	8	Close to med.	No sporodochia
	<i>F. discolor sulphureum</i>	Trace	8	.....	.....

From about 8 to 15 degrees C., *F. discolor sulphureum* develops a loose vegetative mass of mycelium without sporodochia, whereas at about 20 degrees and above macroconidia are produced, more abundantly as the temperature rises, until at 30 degrees a dense pseudopionnotes is produced, with mycelium close to or sunken in the agar. Removal of cultures of this fungus from higher or lower temperatures to room temperature allows again the development of the growth characteristic in the new temperature. (Figures 22 and 27.) The abundant spore production of this fungus at higher temperatures has a bearing

on the accumulation of inoculum in storage houses, and perhaps fields, during the summer months.

Freezing would hardly be expected to injure *Fusaria*. Bartram (3) reported, however; that a *Fusarium* obtained from conifers succumbed to temperatures occurring in winter at Burlington, Vermont. Cultures of *F. oxysporum* exposed to the outside temperature from December 21, 1917, to February 11, 1918, began growing again when brought indoors, and transfers developed normally. This exposure not only involved at times temperatures far below freezing, but, since the cultures were placed on the south side of the building, exposure to the sun and to alternate freezing and thawing.

Similarly, cultures of *F. discolor sulphureum* were uninjured after exposure out of doors for more than a month during the winter. Wilcox, Link, and Pool (75) found that freezing did not injure *F. trichothecioides*. The frequent observation that *Fusaria*, and various other fungi as well, can overwinter in the soil shows quite clearly that low temperatures exert no serious deleterious effect upon them.

EFFECT OF MOISTURE, LIGHT, AGE, FOOD

Relations to moisture.—*Fusaria* grow readily in culture both on rather dry substances such as clover stems, and when submerged in liquid media. Possible oxygen relations involved have not been tested by the writer. That these fungi withstand dry conditions well is indicated by the fact that more than a year after inoculation test tube agar cultures of *F. oxysporum* were still viable; *F. trichothecioides* was still viable after 25 months. The tubes were exposed all this time to the dry and often warm conditions of the laboratory. Humphrey (24, p. 15) reports viability of cultures containing chlamydospores after two years' laboratory dessication in a test tube.

Light.—Cultures grow almost equally well in light or dark, altho, as frequently observed, the colors produced are much more vivid in rather bright light; sunlight on the other hand, is unfavorable.

Age.—That cultures of *Fusaria* may lose their virulence after some period of time on culture media is suggested as a possibility by Sherbakoff (59) and Link (33). The writer has not found that this necessarily holds true. Cultures of *F. oxysporum* obtained as mentioned from Wollenweber's laboratory on February 8, 1915, and which had of course been isolated some time previously, were still able to cause infection of potato stems and rot of tubers about three years later. Appel and Wollenweber (2) note that cultures were still virulent after two years; Edson and Shapovalov (15) found that age did not lessen pathogenicity. It is of course true that cultures may cease to be "high cultures" and produce fewer macroconidia if transferred,

for example, only at long periods. While such cultures may not be as actively virulent as "high cultures," a ready way sometimes to bring about a high culture is by inoculation into the proper host and by subsequent reisolation.

Food.—While the writer has not endeavored to determine specifically which enzymes are produced by certain species of *Fusarium*, he has grown these fungi on various media, both synthetic and complex; it is obvious that they are not restricted in their saprophytic development as to the food used. The work of Hawkins (21) showed that sucrase, maltase, xylanase, and diastase were secreted by both *F. oxysporum* and *F. radicicola*. He found these two fungi to have practically the same effect on the potato.

The situation with regard to the use of starch by various *Fusaria* requires special consideration. Smith and Swingle (63) noted that the starch grains in a rotted potato (causative *Fusarium* not certainly *F. oxysporum*) were not corroded, altho they found some change as evidenced by the staining reaction with iodine. Hawkins (l.c.) observed that starch was not used by the *Fusaria* with which he worked unless first gelatinized. Hawkins sought an explanation in the slowness of action or diffusibility of the enzyme. It may be noted, however, that many writers consider the outer layer of the starch grain to be not homogeneous with the interior. Shapovalov (56) translates Naumov and Pomasski as finding, however, that *F. roseum* Link and *F. subulatum* App. and Wr., which caused "intoxicating bread," dissolved starch in the seeds of cereals.

The writer has investigated the effect of *F. discolor sulphureum* on starch, with results similar to those reported by Hawkins: starch grains in a rotted potato are intact, and stain as darkly with stronger iodine solutions as grains from normal potatoes. The appearance of less blue (more purplish or reddish) staining with dilute iodine is sometimes to be noted with starch from such rotted potatoes, and is of uncertain significance. On gelatinized starch, that is, starch paste made by boiling starch with distilled water, *F. discolor sulphureum* and several other species of *Fusarium* grew fairly well and produced normal spores. It would seem, however, that, barring a possibly less ready separation from the tissue, commercial starch should be procurable from dry rotted potatoes.

To test the effect of prolonged action of fungi and bacteria causing rot of potato tubers, a number of tubers seriously affected with *F. discolor sulphureum* were placed on March 1, 1918, in a jar, and this was covered and set away to allow the continued action of the *Fusarium* as well as any other organisms present. From time to time

samples were removed for examination of the starch grains, the mass being then stirred and set aside. The last examination was made December 24, 1918, at which time, after nearly 10 months of "rotting," the mass still contained entirely normal starch grains. Whether the number was reduced can not be stated, but no grains were found showing partial erosion. The rotting of potato tubers does not necessarily affect the starch present. Edson (15a) has recently published in some detail on this point.*

CROSS-INOCULATIONS

Table V shows the results of some of the cross-inoculations attempted. The data are not presented unless the lesions produced were fairly definite. The rots reported were all obtained at room temperature. The plants inoculated were kept at a greenhouse temperature of about 18 to 24 degrees C.

The evidence presented in Table V seems to indicate that various *Fusaria* may cause rot on certain fruits, such as cucumber, apple, or tomato, the host serving as hardly more than a "culture medium," in these cases, for the development of the *Fusarium*. Potato tubers may also be rotted by several species of *Fusarium*, altho it was found that with certain *Fusaria*, rot was obtained more readily after the potatoes had been dug some little time. Sprouting did not seem to be a necessary corollary. Such forms as *F. trichothecioides* and *F. discolor sulphureum*, could of course produce rot at any time. While it is evident that certain forms, including those just noted, are, under natural conditions, the chief producers of injury to potatoes, it is not apparent that any certain species of *Fusarium* causes rot on tomato, cucumber, and other vegetables.

Cross-inoculation experiments are being continued, since it is evident that the effect of *Fusaria* on different hosts is important from the standpoint of crop rotation.

TABLE V
RESULTS OF CROSS INOCULATIONS WITH FUSARIA

Fusarium	Host tried	Development	Extent of injury 3 or 4 weeks	Remarks
F. oxysporum	Orange fruit	Rot	¼ fruit	Usually a soft rot.
	Tomato fruit	Rot	½ fruit	
	Potato tuber	Rot	Whole tuber	
	Potato plants	Injury	See previous data
	Cucumber fruits	Soft rot	Sterilized soil used
	Apple Fruit	Rot	⅛ fruit	
	Bean plants	No effect noted	.....
F. discolor sulphureum	Pea plants	Slight root injury	Abundant rot
	Cucumber fruits	Soft rot	½ fruit	
	Bean plants	No wilt or rot noted	Light and heavy inoculations made
	Pea plants	No wilt or rot noted	Light and heavy inoculations made
	Potato plants	No "wilt"	See previous data
F. trichothecioides	Potato tuber	Rot, usually dry rot	Whole tuber	See previous data Rind and core particularly attacked
	Orange fruit	Rather soft rot	⅛ fruit	
	Lemon fruit	Rather soft rot	¼ fruit	
	Apple fruit	Rather soft rot	½ fruit	
	Sweet potato	Slight rot	25mm	
	Cucumber fruit	Soft rot	½ fruit	
	Tomato fruit	Soft rot	½ fruit	
	Carrot	Dry rot	¾ carrot	
	Year old potato tuber	Dry rot	½ tuber	
	Newly dug potato	Dry rot	¼ tuber	
	Rotted potato tubers planted	No wilt	.....
F. culmorum	Apple fruit	Slight rot	30 mm	See previous data and Fig. 21
	Potato tuber	Rather soft rot	.....
	Cucumber fruit	Soft rot	¼ fruit	
	Bean plants	No injury noted	.....
Fusarium from bean	Pea plants	No injury noted	See previous data
	Potato tuber	Rot in some cases	25-40 mm	
	Bean plant	Root rots	.....
Fusarium from pea	Pea plant	Slight root injury	Injury occasional
	Potato tuber	Rot in some cases	25-40 mm	
	Pea plant	Root rots and wilt	.....
F. lini	Bean plant	Trace root injury	Injury occasional
	Potato tuber	Some rot	20-40 mm	
F. lycopersici	Cucumber fruit	Rot	¼ fruit	
	Cucumber fruit	Rot	¼ fruit	

DOES THE SUBSTRATUM ALTER THE PATHOGENICITY OF FUSARIA?

Carpenter (8) has reported several *Fusaria* as able to produce rot in potatoes. Sherbakoff (59, p. 100) noted that "Several series of inoculations of potato tubers showed (a) that a considerable number of *Fusaria* can cause more or less rapid decay of the tubers, and (b) that most of the *Fusaria* readily produce rot only after the tubers begin to sprout." Wollenweber (76, p. 37) considered that in general the wilt parasite of one host was not found on living organs of another host, and that "the possibility of the adaptation of the parasite decreases proportionately to the taxonomic distance of the host." He states, however, that "whether such [gradual to other hosts] adaptation occurs and causes changes in the nature of the parasite, indicated in pure culture by differences in general appearance, production of color, etc., has not been determined." Sherbakoff (l. c. p. 103) noted cases of possible mutations or fluctuations and of temporary changes in morphological characters.

Sherbakoff also reported that he had isolated *F. culmorum* from rotted potato both alone and in association with other *Fusaria*. Wollenweber (l. c. p. 45) stated similarly that *F. rubiginosum* App. and Wr. (a probable synonym of *F. culmorum*) caused rot of potatoes at higher temperatures, but irregularly. The writer has isolated organisms similar morphologically to *F. culmorum* several times from rotted potatoes. In an endeavor to determine whether the morphological or physiological nature of these fungi might be altered by continued development on a host other than their characteristic habitat, inoculations were made with *F. lini*, *F. culmorum*, and the *Fusaria* mentioned above as pathogenic to peas and to beans. Some rots of potato tubers were secured with all these forms, particularly with *F. culmorum* (see Figures 23 and 24). As yet these *Fusaria* have not been noticeably changed in morphology or pathology, but experiments should be continued for a much longer time.

THE PRODUCTION OF "TOXIC SUBSTANCES" BY FUSARIA

Lutz (35) has tested the effect of used nutrient solutions, including old *Fusarium* ("*F. solani*") solutions, upon the germination and development of certain fungi. He found that such fungi produced, after a period of growth upon a medium, substances which retarded the germination or growth of fungi grown subsequently in the same medium, even tho more nutrient substances were added; other fungi produced substances acting as accelerators rather than retarders.

Sometimes both types of substances were produced by the same fungus. The effect of these substances was usually destroyed by boiling, or even by lower temperatures. He was, however, unsuccessful in certain other attempts to demonstrate an enzymatic nature of these substances. Old *Fusarium* solutions which had been boiled and exposed to the light, allowed in general a larger growth of the fungus subsequently introduced than did the unheated solutions. He found also that for some of his used solutions, filtration through a clay filter removed the accelerating or retarding substances, altho this filtration did not alter the solutions in other instances. Lutz concludes that "Die von bestimmten Pilzen produzierten wachstumshemmenden resp. fördernden Stoffwechselprodukte, welche durch Kochen zerstört werden, haben keine *spezifische Wirkung* in dem Sinne dass sie immer nur auf Keimung und Wachstum derselben Pilzspezies Einfluss hätten; sie wirken auch auf die Sporen anderer Pilze."

On Currie's (14) solution the writer grew *F. oxysporum*, *F. discolor sulphureum*, the *Fusarium* injurious to peas, *Rhizopus nigricans*, and other fungi. After the fungi grew for different periods of time, these solutions were filtered carefully through filter paper, since a clay filter may, according to Lutz, absorb the products in question. The results of preliminary germination tests made with spores of *F. oxysporum* and *F. discolor sulphureum*, agreed in general with Lutz's results, and indicated that substances were produced by these fungi which were inhibitory to the subsequent germination and early development of the two *Fusaria* in the same solution. Boiling the solutions destroyed this inhibitory action.

Coons (13) reported work showing that *F. oxysporum* produced substances filterable through a Berkefeld filter, which caused early wilting of cuttings from potato vines when immersed in the filtered solution. Lathrop (31) found aldehydes to be produced by *F. cubense* E. F. Sm. Peltier (45) determined that a *Botrytis* produced a "harmful substance" that "may be some inorganic acid other than oxalic, or it may be a toxin of some kind, which, however, is not destroyed by heating to 100 degrees C." Graves (19) found that *Rhizopus nigricans* produced substances that exerted a negatively chemotropic effect upon the fungus greater than the positive chemotropic effect of certain food materials.

The solutions mentioned above, on which the *Fusaria* and *Rhizopus* had grown in Erlenmeyer flasks closed with cotton plugs for different lengths of time, were filtered, and leaves of potato, coleus, ragweed, and other plants, all cut off under water, were introduced (Table VI).

TABLE VI
EFFECTS OF SOLUTIONS IN WHICH FUNGI HAD GROWN, ON THE WILTING OF EXCISED LEAVES

Fungus which had grown in the solution	Time of growth in solution	Treatment of solution after filtration	Plant from which leaves were taken	Approximate time before consp. wilting
				Hours
<i>F. oxysporum</i>	2 months	None	Potato	2*
<i>F. oxysporum</i>	2 months	Boiled	Potato	2
<i>F. oxysporum</i>	2 months	Diluted half with water	Potato	4
<i>F. oxysporum</i>	2 months	Diluted and boiled	Potato	4
<i>F. oxysporum</i>	2 months	None	Coleus	12
<i>F. oxysporum</i>	10 days	None	Potato	24†
<i>F. oxysporum</i>	10 days	None	Lamb's quarters	4†
<i>F. oxysporum</i>	42 days	None	Potato	7
<i>F. oxysporum</i>	42 days	Diluted half with water	Potato	8
<i>F. oxysporum</i>	42 days	Filtered through diatomaceous earth	Potato	10
<i>F. oxysporum</i>	42 days	None	Ragweed	7
<i>F. oxysporum</i>	42 days	Diluted half with water	Ragweed	7
<i>F. oxysporum</i>	42 days	Filtered through diatomaceous earth	Ragweed	8
<i>F. discolor sulphureum</i>	2 months	None	Potato	2
<i>F. discolor sulphureum</i>	2 months	Boiled	Potato	2
<i>F. discolor sulphureum</i>	42 days	None	Potato	7
<i>F. discolor sulphureum</i>	42 days	Boiled	Potato	8
<i>F. discolor sulphureum</i>	42 days	None	Ragweed	6
<i>F. discolor sulphureum</i>	42 days	Boiled	Ragweed	6
<i>Fusarium</i> from pea	2 months	None	Potato	3
<i>Fusarium</i> from pea	2 months	None	Coleus	12
<i>Fusarium</i> from pea	2 months	Diluted half with water and neutralized	Potato	4
<i>Fusarium</i> from pea	2 months	Diluted as above and boiled	Potato	4
<i>Fusarium</i> from pea	2 months	Diluted with 3 vols. water and neutralized	Potato	4
<i>Fusarium</i> from pea	2 months	Diluted as above and boiled	Potato	4
<i>Fusarium</i> from pea	42 days	None	Potato	7
<i>Fusarium</i> from pea	42 days	Made slightly alkaline	Potato	7†
<i>Fusarium</i> from pea	42 days	Diluted with 3 vols. water	Potato	8
<i>Fusarium</i> from pea	42 days	Boiled	Potato	7
<i>Fusarium</i> from pea	42 days	None	Ragweed	4
<i>Fusarium</i> from pea	42 days	Made slightly alkaline	Ragweed	4
<i>Fusarium</i> from pea	42 days	Diluted with 3 vols. water	Ragweed	5
<i>Fusarium</i> from pea	42 days	Boiled	Ragweed	3
<i>Rhizopus nigricans</i>	2 months	None	Potato	1½
<i>Rhizopus nigricans</i>	2 months	None	Coleus	5
<i>Rhizopus nigricans</i>	42 days	None	Potato	7
<i>Rhizopus nigricans</i>	42 days	Boiled	Potato	6
<i>Rhizopus nigricans</i>	42 days	Boiled	Ragweed	6
<i>Rhizopus nigricans</i>	42 days	None	Ragweed	6
None	None	Curries, freshly made	Potato	24+
None	None	Curries, freshly made, boiled	Potato	24+
None	None	Curries, 42 days old	Potato	16
None	None	Curries, 42 days old	Ragweed	10
None	None	Curries, 42 days old, boiled	Potato	14
None	None	Curries, 42 days old, boiled	Ragweed	10
None	None	Tap or distilled water	Potato	48+
None	None	Tap or distilled water	Coleus	48+
None	None	Tap or distilled water	Ragweed	24+

* Potato leaves for tests at any one time were taken from plants of the same age and in similar condition. For the two-months-old solutions, the leaves were from full-grown potato plants.

† Tests after ten days reported in only this case, since with all the solutions it was evident that no particular development of "toxic substance" had ensued.

‡ Wilt less pronounced than in preceding case.

Tests were also run with other *Fusaria*, and with *Rhizoctonia* and *Penicillium*. Wilting of excised leaves of various plants ensued more rapidly in old solutions. Wilting occurred even after considerable dilution. It is not to be explained on the basis of acidity. It is to be noted that no specific action is evident between the fungi tried and any one plant; potato leaves wilt as readily in old *Rhizopus* solutions as in solutions in which *F. oxysporum* had grown. This is in agreement with Lutz's results in growing fungi in old solutions. A difference exists, in that boiling the solution exerts no evident effect upon the action of old solutions on the leaves. In certain cases leaves took on a crinkled, distorted, or mosaic appearance, resembling sometimes the condition obtained by Smith (62, pl. 63).

"MIXED CULTURE" RELATIONSHIPS

Nature seldom works with pure cultures. The interrelationships of various organisms forming the mixed cultures of nature have received little study (see Rahn 54, p. 181). In view of the frequency with which various bacteria may be associated with *Fusaria* in wilt diseases and tuber rots, the writer undertook tests to ascertain some relations between certain bacteria and *Fusaria*.

It is a matter of common observation that fungi belonging to the genus *Fusarium* grow vigorously on any of the common culture media. Indeed, *Fusaria* are often troublesome as saprophytes in isolation, dilution, and other cultures of various organisms, on account of the vigor and rapidity of their growth. The writer has observed *Fusaria* to grow over and "swamp" colonies of *Penicillium* and other fungi.

When, for example, two colonies of the same or of different fungi develop in a Petri dish, there is often a mutual cessation of growth at about the point where the colonies meet. Aside from the possible presence of any growth-arresting substance, there may be a lack of food, or possibly some mechanical obstruction of growth from the presence of hyphae, in the case of fungi. With a bacterial and fungous colony, however, the former should offer less mechanical impediment to the growth of the latter.

Rahn (53) and others have shown that bacteria may produce growth-arresting substances, inhibiting more especially the further growth of the same organism. Elliot (16) has emphasized the changes in the mycelial characters of some species of *Alternaria* due to contact with colonies of certain bacteria. Sherbakoff (59, p. 214 f.) found chlamydospores especially abundant when *Fusaria* grew in the presence of bacteria.

In the writer's experiments, Petri dishes of potato dextrose agar were used, inoculated at the center with the *Fusarium*, and midway on the radii with bacteria at the same time, then incubated until the colonies reached each other. In other cases the bacteria were first inoculated in the center and, since the *Fusaria* usually grow more rapidly than the bacteria, after incubation from one day to three days the *Fusaria* were inoculated on the radii. *F. oxysporum*, *F. discolor sulphureum*, and the *Fusaria* from the bean and the pea were employed. *Bacillus atrosepticus* v. Hall, obtained through the courtesy of Dr. Morse, was used, since the blackleg organism is often found in both the stems and the tubers of potatoes. *B. carotovorus* Jones, certain undetermined species of bacteria isolated from rotted potato tubers and stems, *Pseudomonas phaseoli* E. F. Sm., and some common saprophytes such as *Bacillus subtilis* (Ehr.) Cohn and *B. prodigiosus* (Ehr.) Fleug., were also employed. Figures 25 to 30, with explanations in the list of plates, show in detail characteristic results. These experiments, which were duplicated several times, showed that in general a colony of bacteria which exerted a retarding influence on one species of *Fusarium*, exerted a similar influence on the other three species. Here again no specificity of "toxic substance" for any certain species of fungus was noted. Some bacteria exerted no observed influence, some accelerated, and some retarded growth of the fungus. The production of mycelium was sometimes changed in quantity, or the color reaction upon the medium was altered. On the whole the *Fusaria* were very tolerant to the presence of bacteria. No marked alteration of the mycelium or spores was found as a result of the action of the bacterial colonies on the fungus. While the writer has no reason to doubt the authenticity or vigor of the bacterial cultures used, he has not checked this point. Table VII summarizes the observations.

TABLE VII
EFFECT OF BACTERIA ON CERTAIN FUSARIA

	<i>Bacillus atrosepticus</i>	<i>Ps. phaseoli</i>	From rotted potato stem	From rotted seed piece	<i>B. subtilis</i>
<i>F. oxysporum</i>	Slight alteration of growth; aerial mycelium marked	Retarded growth	Retarded growth	Retarded growth medium colored	No change
<i>F. discolor sulphureum</i>	No effect noted	Retarded growth	Retarded growth	Marked retardation	No change
<i>F. from bean</i>	Growth somewhat accelerated, or no change*	Retarded growth	Retarded growth	Retardation	Acceleration* or no change
<i>F. from pea</i>	No effect noted	Retarded growth	Retarded growth	.....	No change

* Acceleration of growth did not ensue in every trial. In general, however, the same results were secured in the different tests.

GENERAL DISCUSSION

In considering Fusaria and the diseases they induce, we may first consider these fungi as vigorously growing saprophytes. Their longevity in the soil is a matter of prime importance.

Bolley, in 1901 (5), showed that soil became "flax sick" because of an accumulation of *F. lini*; he stated that when once serious in the soil, "It can live from year to year upon the humus of the soil.... The fungus is able to live in the soil for many years without the presence of a flax crop to feed upon." Orton (40), referring to *F. oxysporum* in the San Joaquin Valley, California, stated that the fungus "may be present in nature in some of these alluvial soils" and at any rate soon accumulated sufficiently in the soil to render potato growing unprofitable. Jensen (26) reported the isolation of *F. oxysporum* from soil from the eastern part of the United States.

It is significant that Pratt (49,50,51,52) found *F. trichothecioides*, *F. radicola*, and apparently also *F. oxysporum*, in virgin western soils. Werkenthin (74) found in Texas "that the virgin soil contained fungi which are known to be parasitic to cultivated plants, e.g., *Fusarium Solani* (Mart). Sacc., *Fusarium oxysporum* Schlecht., and *Fusarium radicola* Wollenweber." These fungi he considered "true inhabitants of the soil." Taylor (68) found *Fusarium* spp. to a depth of 24 inches, in Rhode Island. Coons (13) obtained what was apparently *F. oxysporum* from native Michigan soils.

There is evidence, then, that *F. oxysporum* may be present in many soils, and may become of considerable importance as succeeding crops of potatoes are grown; it must increase greatly from its growth in roots and stems of parasitized plants, and especially from its development on the dying potato stems and their débris. Such saprophytic fungi are able to withstand various unfavorable environmental conditions and persist in the soil through the production of microconidia and macroconidia, chlamydospores, or "perennating mycelium." In their growth, some Fusaria at least are able to compete successfully with various bacteria and other organisms with which they come in contact.

While Fusaria are active saprophytes, there can be, on the other hand, no question as to their seriousness as plant parasites; their abundant saprophytic growth only renders their control in some respects more difficult. Despite their semi-parasitic nature, many Fusaria, such as *F. oxysporum*, exhibit what amounts to a considerable specificity of parasitism to certain crops. *F. oxysporum*, however, can attack any part of the potato plant; stem, stolon, root, tuber, or even leaf. If the fungus is present in abundance, it can cause a com-

plete rotting off of the stems. It is not surprising, then, that from plants showing atypical symptoms of wilt in the field, *F. oxysporum* should be isolated, especially when the soil and weather conditions are propitious. The Early Ohio variety has been found to be commonly affected, particularly in the Red River Valley. This may be correlated with the fact that the Early Ohio remains through a considerable period in late summer in a condition of slow maturity and lessened vigor.

In regard to the cause of wilting in potato plants into which *F. oxysporum* has gained entrance, a common explanation is that of mechanical vascular clogging. Link (35) considers the killing of the root system to be as important as this clogging, and Coons (13, p. 302) would add also the systemic poisoning from the production of substances by the fungus. The writer's experiments indicate that the fungus does produce toxic substances, but that various other fungi produce substances equally toxic, the only specificity being in the fact that the other fungi tried are ordinarily unable to gain entrance into the tissues of the plant. It would seem, however, that the three factors mentioned may operate together, with the addition in cases of foot rot of a considerable rotting of the underground portions of the potato plant.

The association of injury to the potato stem from *Rhizoctonia* or *Colletotrichum atromentarium* (Berk. & Br.) Taub. (67) and of *F. oxysporum* within such stems, and the occasional coincident occurrence of bacteria, *Verticillium*, or other fungi with *F. oxysporum* indicate that *Fusarium* wilt ensues more readily when the plant is weakened, and that other organisms may follow or aid the *Fusarium* in causing injury to the potato plant.

Tisdale (70) has shown that the method of infection by *F. lini* is through root hairs, stomata, or epidermis; in resistant flax the plant was enabled to cork out the perhaps weakened hyphae, which could, however, gain preliminary entrance into the plant. He found further that *F. conglutinans* could penetrate the root hairs of flax, as it normally penetrated cabbage, but in flax it did not develop far. *F. lini* could also probably penetrate the young root hairs of cabbage.

While rots of potato tubers are attainable in the laboratory with various *Fusaria*, in Minnesota the economically important *Fusarium* causing rot of tubers is, as far as the writer's evidence goes, *F. discolor sulphureum*. *F. oxysporum* may injure the tuber somewhat by development at the stem end or considerably in the vascular system, or occasionally by causing a rot; other *Fusaria* more rarely cause dry rot alone or in association with other organisms. *F. discolor sulphureum* evidently lives over especially in storage houses; the writer

has observed it in the fall growing luxuriantly, particularly on dirt floors and walls and on débris in potato houses that had held potatoes the previous year.

Infection of the tuber may sometimes apparently ensue from contamination with the organism from the field. Once this fungus gains entrance it can develop at ordinary temperatures regardless of the humidity in storage, tho lower humidity obviously lessens the liability of infection. Relatively low temperatures, particularly cold storage, (1 to 3 degrees C.) allow but slight progress of the disease.

While *F. discolor sulphureum* ordinarily gains entrance through wounds, it is worthy of note as reported above that it may sometimes evidently infect through lenticels. In this connection it may be noted that Pratt (49) found that *F. radicicola* might infect the tuber through the stem end, lenticel, or eye; Wilcox, Link, and Pool (75) and Pratt (51) found that *F. trichothecioides*, on the other hand, infected only through bruises or other injury. Experiments and observations indicate that tubers become naturally infected with *F. discolor sulphureum* principally through wounds.

Tomato, cucumber, and some other fruits and various vegetables, especially when mature, may be rotted by several Fusaria. Numerous other fungi, such as *Penicillium* spp., may also rot these plant parts; the action is hardly more than saprophytic growth upon easily available food material. While various fungi such as *Penicillium* spp., *Aspergillus* spp., *Stysanus stemonitis*, *Verticillium* sp., *Alternaria* sp., are often found on or in rotted tubers or on healthy tubers, inoculation experiments failed to show any noteworthy ability of these fungi to rot the potato. The normal tuber is not an available source of food for them. Certain Fusaria are also unable to utilize readily the potato tuber as a food supply.

CONTROL MEASURES

POTATO WILT

The methods of control ordinarily recommended are clipping the stem ends and rotation of crops. The former method, while of undoubted value in removing some infection as well as the somewhat weaker eyes near the stem end, is not effective in seriously infected soils. Whether or not *F. oxysporum* occurs naturally in Minnesota soils, it is now widely distributed in the potato growing regions. Observational evidence has failed to show that this fungus seriously attacks other crops in the state. It undoubtedly remains in some abundance in Minnesota soils for a considerable time.

It seems to the writer that the observation that the *Fusarium* causing potato wilt in Minnesota attacks the plants more especially at the time when blossoming, tuber setting, and hot weather have reduced the vigor of these plants, offers considerable hope in the development of control measures. From this standpoint the utilization of more vigorous strains of potatoes, rotation of crops, improvement of the seedbed, clean culture, and other factors tending to produce more vigorous plants likewise lessen the liability to attack by *F. oxysporum*.

The writer is uncertain as to the interpretation to place upon the data presented by Manns (36, p. 317-319) and considered as tending to show that the "fungus will average in sick fields as great a percentage in reduction under favorable conditions as under drouth." Manns evidently bases this conclusion on the fact that a three-year rotation plot at the Ohio station yielded in 1909 only 69 bushels per acre, whereas the county averaged 186 bushels per acre. It would seem, however, that throughout that county, in which the wilt had presumably been present previously (l.c., p. 311), it could not have greatly reduced the yield in 1909 despite the supposed higher percentage of seed infection in 1908 (l.c., p. 319; see also yield of spray plot, as noted below). Of course this does not explain the low yield in the rotation plot at the Ohio station in 1909.

The work of Manns with bordeaux mixture is also significant. He found that despite the fact that "the only active factor at work in 1909 in reducing the yield on the area plotted for spraying was the work of the *Fusarium* blight, which was very prevalent . . . the growth in all sprayed plots continued from one to three weeks longer than in the unsprayed," with an average yield of 170.36 bushels per acre in the unsprayed and 181.72 bushels per acre in the sprayed plots. He adds, "The writer is satisfied that spraying heavily four times during the season does somewhat retard the action of the *Fusarium* fungus. Just how the results are brought about can not be satisfactorily explained." It would seem that the explanation may lie in the increased vitality of plants which are sprayed, and which can thus resist the action of the semi-parasitic *F. oxysporum*. Stewart (66) had previously in New York State obtained a yield of 266 bushels per acre from tubers obtained from wilted vines and in which "when cut at the stem end, blackened fibers are seen penetrating the flesh to a considerable distance." This plot was sprayed thoroly eight or nine times with bordeaux mixture. While it is not certain that Stewart was dealing with *F. oxysporum* wilt, the results obtained are comparable to those secured by Manns.

The writer has obtained as yet only empirical and fragmentary evidence as to the effect of spraying upon the occurrence of wilt in Minnesota. In the northeastern states, where spraying is commonly practiced, wilt is not prevalent. It must not be forgotten, however, that in this region cool weather and other conditions are more favorable to the production of healthy and vigorous plants than in warmer regions.

The results secured in Minnesota by A. G. Tolaas and certain county agents in the use of seed-plot methods, including selection, treatment, rotation, and good cultural conditions, indicate that wilt may be lessened by methods which tend to add vigor to the plants. A. G. Newhall, in 1918, found a case in point: A field in Cass County, a portion of which had received some care, had 15 per cent of wilt, whereas in another portion in which negligence had allowed weeds to develop and the potato plants to become less thrifty, 30 per cent of wilt occurred.

Removal of débris from a field that had grown potatoes would lessen considerably the amount of culture medium for the *Fusarium*. The consideration involved as to fungi in returning such débris to the field after a period of rotting, is undetermined.

POTATO DRY ROT

Control measures that may be used against the rot caused by *F. discolor sulphureum* have not been found to be different from those recommended by various writers against other fusarial dry rots. Highly important is more careful handling of potatoes during and after digging to avoid cuts, bruises, and injuries, since the fungus attacks the tubers ordinarily and most easily through wounds. Storage cold enough to prevent absolutely the development of this rot is hardly attainable in any storage facilities possessed by the average grower, except possibly in the use of pits in the field. Considerably less infection would probably result, however, if the storage rooms were thoroly disinfected before potatoes were put in, and cleaned out carefully after the potatoes were removed. A disinfection of the tubers before storage would probably be commercially profitable, at least in the case of seed potatoes.

Control measures against root rots of truck crops are indicated in the rotation of crops and the most favorable growing conditions for the crop. Careful handling and clean cool storage of fruits and vegetables subject to *Fusarium* rots will reduce the injury.

SUMMARY

1. *Fusarium oxysporum* Schl. is the cause of one of the most serious diseases of the potato plant in Minnesota.

2. This fungus characteristically produces the symptoms known as wilt. It attacks the roots and lower stem of the potato plant, particularly during the blossoming and tuber setting periods, when the weather is likely to be unfavorable to the potato, tho not to the fungus. *F. oxysporum* can moreover attack any part of the potato plant, and under certain conditions, particularly in wet soil, causes darkening and rotting of the stem and other symptoms not typical of wilt. It may rot the seed tuber under field conditions.

3. As a saprophyte, *F. oxysporum* grows vigorously on the affected potato plants, accumulates in considerable abundance in the soil throughout the season, and persists for some time. In the fall it may attack plants which have previously produced a normal crop of tubers.

4. The strains of *F. oxysporum* used were not, under ordinary conditions, sufficiently active parasites to cause infection of younger potato plants from artificial inoculations of the soil or seed tuber. At higher temperatures, symptoms of disease may occur. If the soil is inoculated heavily, rotting of the seed tuber and of the sprout or stem may result.

5. Wilted plants do not necessarily result from planting seed tubers from affected plants. While such "seed" is less satisfactory than tubers produced under healthy vines, other measures in addition to seed selection or clipping off the stem ends are necessary to avoid wilt.

6. While *F. oxysporum* is largely confined to the potato in Minnesota, its habits are for the most part hemi-parasitic.

7. The danger of serious infection by the wilt Fusarium is lessened by measures tending to add to the vigor of the plants, particularly during the latter part of the season.

8. *Fusarium discolor sulphureum* is the common cause of storage dry rot of potato tubers in Minnesota.

9. This fungus gains entrance commonly through wounds, tho the rot may sometimes be induced by applying the fungus to the uninjured surface of the tuber.

10. Tubers from normal potato vines rot as readily as those from "constitutionally degenerate" plants, and as readily as tubers showing frost necrosis. None of the varieties of potatoes tested was found to be resistant to this tuber dry rot.

11. Rot may develop on unsprouted tubers, and under dry conditions. Very slight rot may develop even at temperatures below 2 degrees C.

12. At temperatures below about 16 degrees C., *F. discolor sulphureum* produces more abundant aerial mycelium; at temperatures of from 20 to 30 degrees C., a dense pseudopionnotes.

13. The starch grains in the tubers affected with dry rot are not appreciably affected.

14. *F. discolor sulphureum* does not naturally cause a wilt of potato plants, but infected seed tubers may produce less vigorous sprouts, or even no sprouts.

15. While other Fusaria, such as *F. oxysporum* and *F. culmorum* may cause rot of potato tubers, such rots have been found to be of little economic importance in storage.

16. Careful handling of tubers and the maintenance of clean cold storage conditions, are important prophylactic measures against the storage rot caused by *F. discolor sulphureum*.

17. Fusarium root rots of *Pisum sativum* and of *Phaseolus vulgaris* are of importance in Minnesota.

18. Ear rots of *Zea mays* due to Fusaria, probably including *F. culmorum*, are common in the state.

19. Cross-inoculations indicate that wilt or root rot producing Fusaria may exhibit a selective tendency in their more common occurrence on certain species of host plants, altho hemi-parasitic in that their action may be more distinctly influenced by conditions unfavorable to the host.

20. A temperature at which the host develops poorly may allow an active development of the attacking Fusarium.

21. Isolations and cross-inoculations demonstrate that no single species of Fusarium is chiefly responsible for the common storage rots of vegetables and of cucumber and tomato fruits.

22. Fusaria produced substances in old solutions that inhibited the germination of spores of the same or other fungi. After boiling, such old solutions allowed normal germination.

23. Substances detrimental to such plants as potato, coleus, and ragweed, as shown by the wilting of excised leaves when placed in solutions, were also produced by Fusaria and other fungi in cultures. This injurious effect persisted after boiling, neutralization, or some dilution of the solutions. Specific fungi did not produce substances selectively injurious to any one or more plants.

24. Fusaria are, in general, little influenced by bacteria, tho some bacteria may influence the rate of growth of Fusaria.

25. The Fusaria examined could withstand considerable dessication, exposure to low temperatures or to alternate freezing and thawing, and can utilize a wide variety of food substances. Altho important parasites, Fusaria are efficient saprophytes.

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EXPLANATION OF PLATES

- Figure 1. Plant showing typical wilting. Illustration by the courtesy of H. A. Edson of the United States Department of Agriculture. Taken in a field in Clay County, Minnesota, August 11, 1917.
- Figure 2. Rather early stage of wilting. Taken by Dr. Edson, also in Clay County, August 11, 1917.
- Figure 3. Plants collected August 23, 1918, from Clay County, illustrating the browning and rotting of the lower stems and of the roots. One plant also injured by stalk borer. Isolations yielded *Fusarium oxysporum* from these and similar plants.
- Figure 4. Plants showing similar and serious injury from foot rot, collected August 22 and 23, 1918, from Polk and Clay counties. The large plant illustrates also the external production of fungus after having been in a damp place about two days.
- Figure 5. Tubers from plants showing foot rot, collected in Polk County, August 22, 1918. *F. oxysporum* and secondary fungi and bacteria present, causing a rather soft rot of the tubers. This rot was not ordinarily foul smelling. The blackening shows some tendency to follow the fibro-vascular bundles.
- Figure 6. Seed piece inoculated with *F. oxysporum*, received February 8, 1915, from W. A. Orton. (No. 3394 from Wollenweber's laboratory.) Inoculation September, 1917. The seed piece had rotted, the fungus was present in the stem. Reisolations yielded *F. oxysporum*.
- Figure 7. Cage heated by carbon electric lamps to secure higher temperature.
- Figure 8. Results of rather heavy inoculation of sterilized soil with *F. oxysporum* in the warmed cage. Seed piece rotted, one stem rotted off, other injured at the base. March, 1918.
- Figure 9. A case similar to Figure 8. Stems rotted off or seriously injured at the base. March, 1918.
- Figure 10. On the left, plant growing in the warm chamber in sterilized soil infected with *F. oxysporum*. Moist conditions did not allow a serious wilting, but the plant is affected, particularly as indicated by the upper leaves. On the right, check grown from the same seed in sterilized soil. February, 1918.
- Figure 11. Affected plant growing in artificially infected soil. The lower leaves have fallen and the plant is unthrifty. February, 1918.
- Figure 12. Surface view of tubers affected with *F. discolor sulphureum* from Beardsley. The wounds from which infection occurred can be seen on the surface. January, 1918.
- Figure 13. Longitudinal sections of the tubers shown in Figure 12. The rotted tissue is dark brown or blackish, containing some "pockets" filled with mycelium and sporodochia of the fungus.
- Figure 14. Stem and eye end infection of tubers from Clay County and characteristic of the rather early stage of a considerable infection in that region. Received December 10, 1917.

- Figure 15. Effect of injury, moisture, and temperature on the development of rot by *F. discolor sulphureum*. Figures A to E, inclusive, no injury to the surface; inoculum applied to the uninjured epidermis. Figures F, G, and H, slight injury to the surface before inoculation. Figures I to L, considerable wounding of surface previous to inoculation. Figures A and B, room temperature, damp. Figures C and D, room temperature, in a dessicator. Figure E, icebox (8 to 10 degrees C.), damp. Figure F, room temperature, damp. Figure G, room temperature, dessicator. Figure H, icebox, damp. Figure I, room temperature, damp. Figure J, room temperature, dessicator. Figure K, room temperature and room humidity. Figure L, icebox, damp.
- Figure 16. Weak plant secured from planting seed partially rotted with *F. discolor sulphureum*. March, 1918.
- Figure 17. Healthy plant from seed tuber planted at same time as that of plant shown in Figure 16. Some rot on seed when planted. The rot did not, however, progress much. March, 1918.
- Figure 18. At left, base of plant shown in Figure 16, seed rotted; center, base of plant shown in Figure 17, seed healthy at insertion of stem. At right, another plant similar to the one on the left. March, 1918.
- Figure 19. Pea seeds rotted and roots and lower stems of young plants affected with *Fusarium* isolated from pea plants. Greenhouse inoculations, September, 1917.
- Figure 20. Four tubers at left show slight rot, with *F. discolor sulphureum* developed at 1.1 to 1.7 degrees C. Plugs cut out of potatoes in inoculating. The browned vascular ring in some of these tubers is due to frost necrosis, which had developed prior to the subjection to cold storage. Previous experiments demonstrated that this slight necrosis had no influence on the rate of rotting. At the right, a tuber almost wholly rotted when placed in cold storage. The rot progressed little at the temperature mentioned. This tuber was cut before being put in cold storage and shows the development of some mycelium on the cut surface. Duration of experiment, 31 days, March 16 to April 16, 1918.
- Figure 21. Rot of potatoes from *F. discolor sulphureum* at 8 to 10 degrees C., artificial inoculation, two weeks' development.
- Figure 22. *F. discolor sulphureum*: center of plate, mycelium produced at 8 to 10 degrees C.; area of less abundant mycelium produced at room temperature, containing many small sporodochia not shown clearly; circumference, mycelium produced again at 8 to 10 degrees C.
- Figure 23. At the right, tuber rot secured at 25 degrees C. with *F. culmorum* from wheat; at left, rot by same fungus at room temperature (about 18 to 20 degrees C.). Time, two weeks.
- Figure 24. Rot started by *F. lini* on potato tuber. Time, two weeks.
- Figure 25. *F. oxysporum* inoculated January 25, 1918, in the center. The stained area (dark red in natural color) shows the area occupied by a colony of bacteria obtained originally from a rotted seed piece and as yet unidentified, over which the fungus grew slowly, as indicated by the lines marking dates. Opposite this a colony of *Bacillus atrosepticus* was present, but exerted no influence on growth or production of color. A colony of *Aspergillus* at the margin opposite the stained area checked the growth of the *Fusarium*. View from lower face of Petri dish.

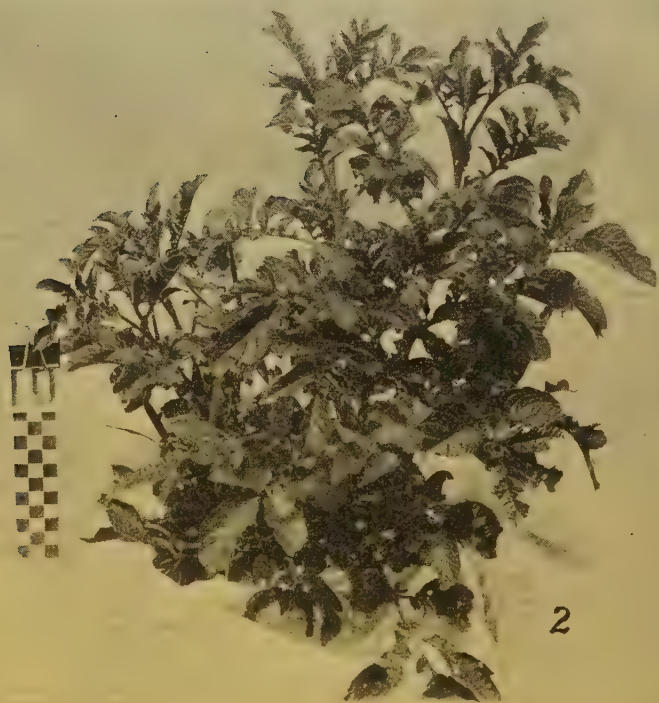
Figure 26. View from above, showing mycelium of *F. oxysporum* growing over a colony of *B. subtilis*: aerial mycelium marks the margin; no pause in the growth. The radii, etc., on the opposite side are due possibly to shrinkage of the medium.

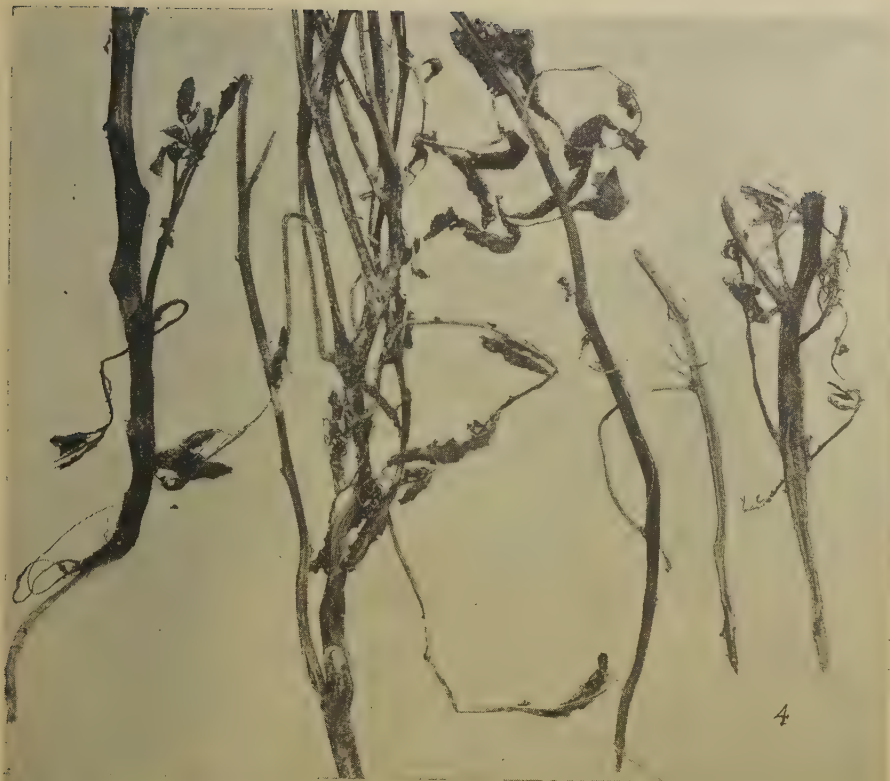
Figure 27. *F. discolor sulphureum* retarded by a colony of bacteria (the same species of bacteria mentioned for Figure 25, obtained from a rotted seed tuber). The fungus eventually grew completely over this colony; the conidia and mycelium produced thereon appeared normal microscopically. Opposite, a colony of *Bacillus atrosepticus* had exerted no influence upon the growth. This figure illustrates the ample macroconidial production at room temperature. View from above.

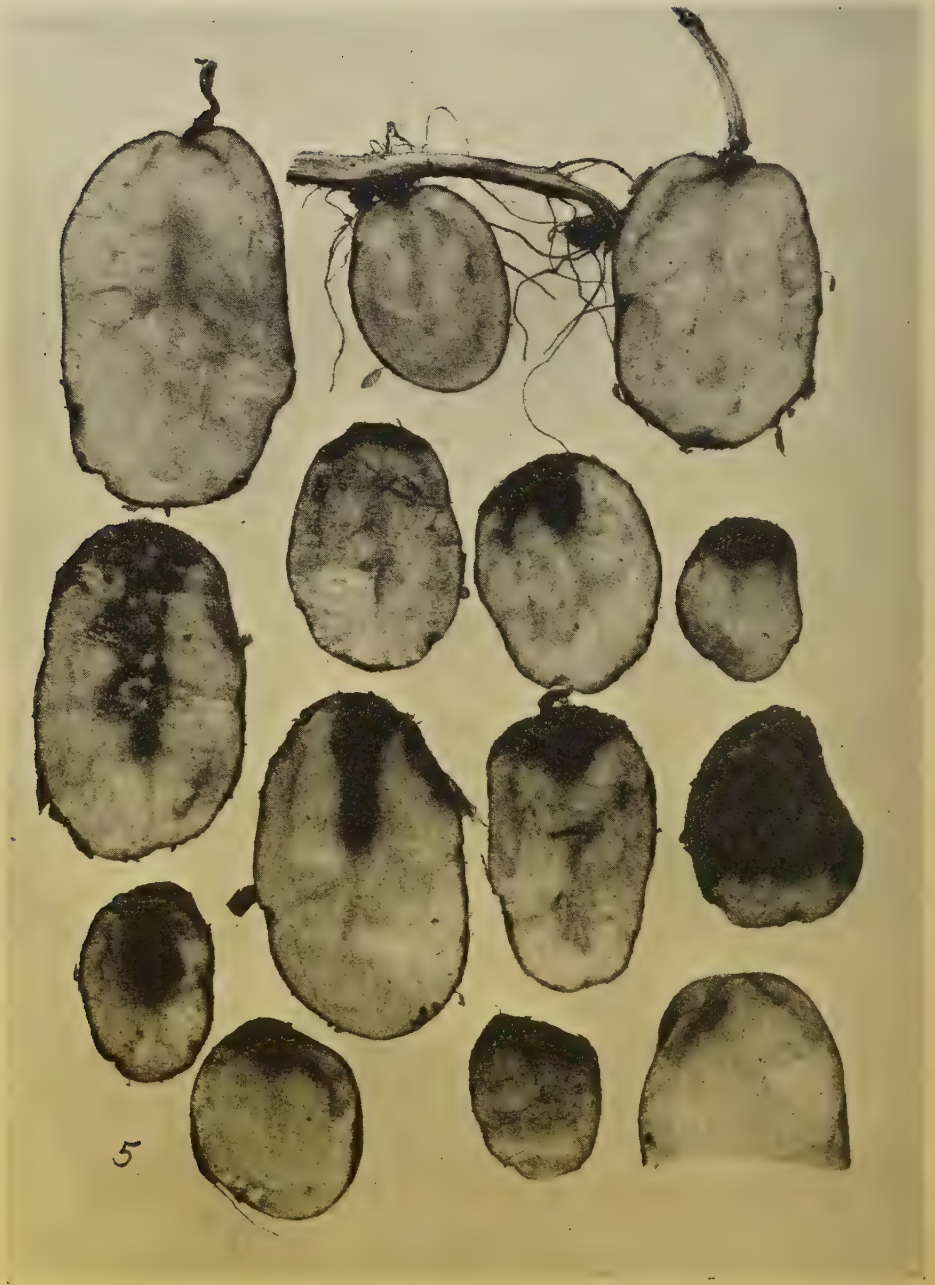
Figure 28. Fusarium from bean plant. The irregular bacterial colony, checking growth somewhat, is *Pseudomonas phaseoli*. (The fungus finally grew entirely over this colony, but more slowly.) Opposite roundish colony is *B. subtilis*. The growth of the colony was noticeably accelerated when this colony was reached, just as the growth has been accelerated on the lower side, where the fungus has pushed out over a colony of *B. atrosepticus*. "Growth arresting and accelerating" substances are evidently produced. The organisms shown in Figures 25 to 28 grew on potato dextrose agar under a bell jar at room temperature. Inoculations January 25, 1918, photographs February 5, 1918.

Figure 29. At right, relation between bacteria from a soft-rotted potato and (1) *F. oxysporum*, (2) *F. discolor sulphureum*, (3) Fusarium from pea, (4) Fusarium from bean. Bacteria inoculated in center November 9, 1918, fungi inoculations November 12, photograph November 15. The growth of the fungi was somewhat retarded, and the bacteria tended to grow between the fungous colonies. At left, *B. atrosepticus* in center. Fusaria numbered as at right, inoculations and photographs same date.

Figure 30. At right, *B. subtilis* in center, exerting little influence on the Fusaria. At left, a colony of bacteria isolated from a potato stem has diffused substances through the medium checking equally the growth of the four Fusaria. Reciprocally, the bacterial colony ceased to enlarge. Inoculations in both plates: bacteria, November 9, 1918. Fusaria, November 14, photograph November 25.

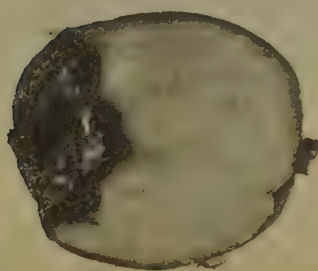
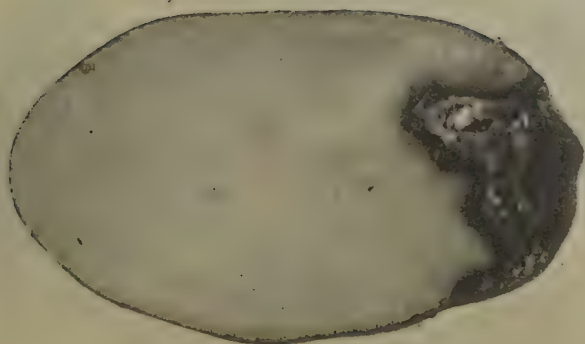




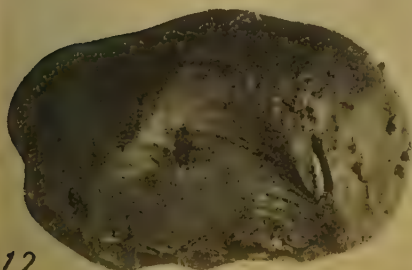
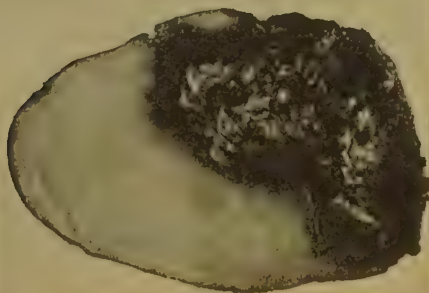
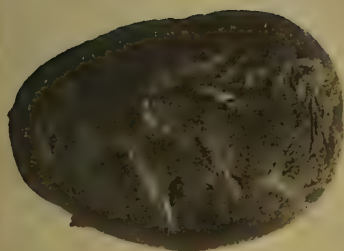






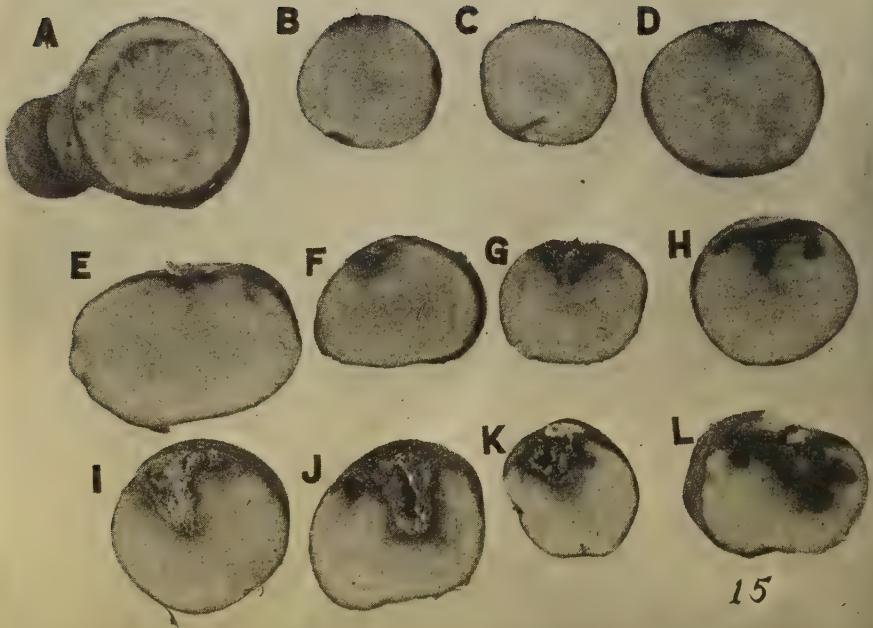


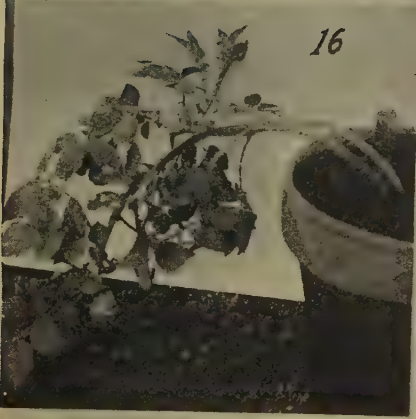
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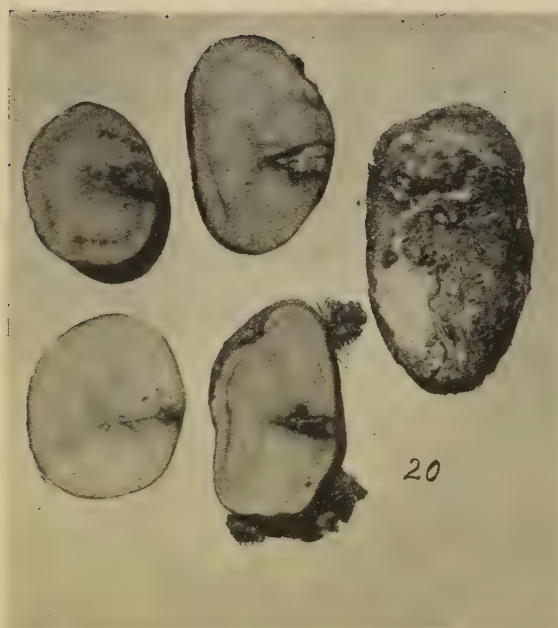


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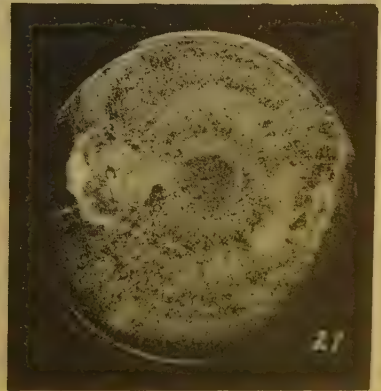
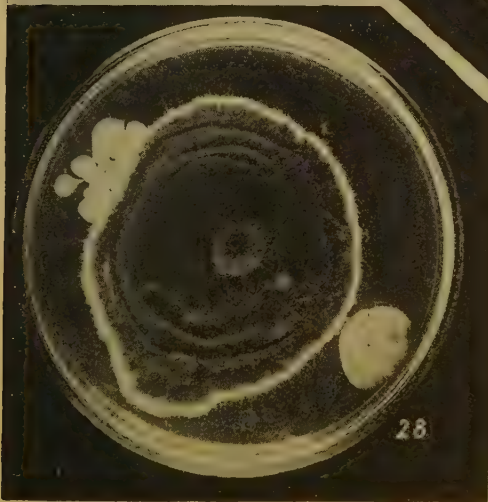
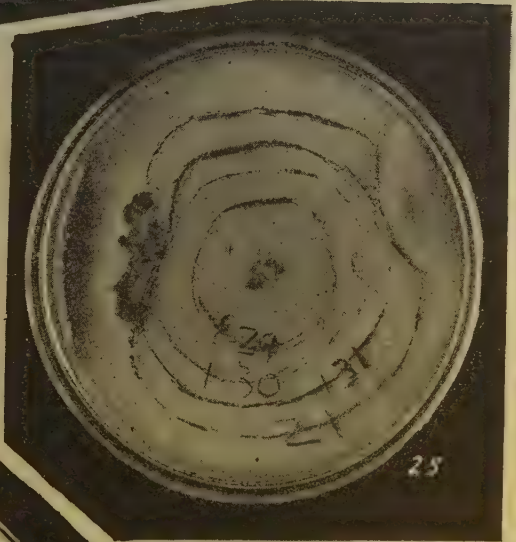
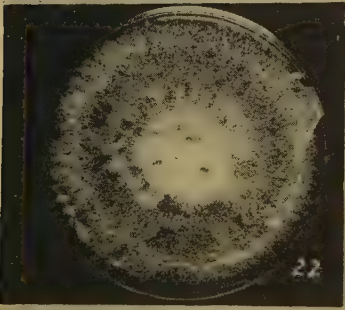
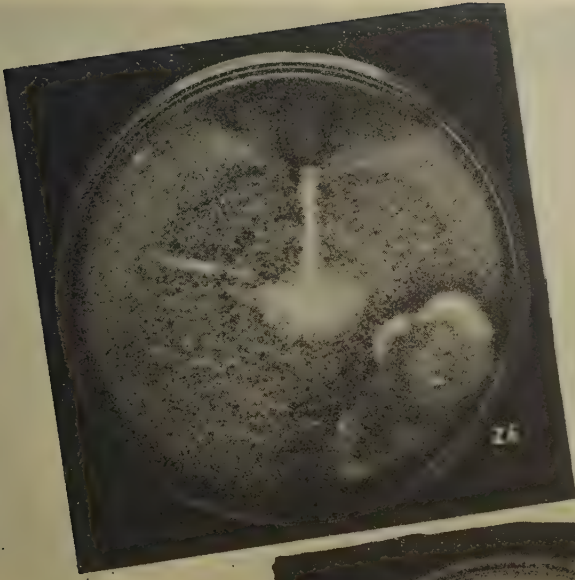
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Good Results from Spraying in Minnesota



These two piles of Rural New Yorker potatoes came from the same sized experimental plots, two square rods, on the University Farm at St. Paul. No. 1 was unsprayed and weighed 43 pounds; No. 2 was sprayed three times with 5:5:50 Bordeaux mixture and weighed 100 pounds.



Floyd Riggs, Bertha, Minn.

By G. R. BISBY and
A. G. TOLAAS



IT IS PROBABLY not generally known that some of the first experiments with Bordeaux mixture in the United States were performed in Minnesota. In 1888, the year he began work at University Farm, St. Paul, the late Professor Green sprayed potatoes with Bordeaux mixture and other preparations. Beside the purpose of testing insecticides, Professor Green stated that he "wanted to see the effect of these insecticides (and the fungicides used) might have in arresting or preventing blight and other diseases of the foilage and their subsequent effect on the total yield of the crop." He made "Gironde or Bordeaux mixture" as follows: Thirty-two pounds of copper sulfate were dissolved in 58 gallons of water, 60 pounds of rich lime were slaked in 15 gallons of water, and the latter was poured into the copper sulfate solution. This was applied to the plants with a small broom. At first he "thought the mixture of little account, and feared that it would kill the potatoes as well as the bugs," but after the second application reported a decided dark healthy color to the leaves. Table No. 1 is taken from his report in Supplement I to the Fifth Biennial Report of the Board of Regents and gives the yields obtained.

From this experiment Professor Green was quite interested in the possibilities of Bordeaux mixture. In 1893 he had opportunity to try it further in a cooperative way on a plot of potatoes near the University Farm. The part of this field which was sprayed yielded at the rate of 210 bushels per acre, the unsprayed portion at the rate of 160 bushels per acre.

Tests on the station plots in 1894 were unsuccessful, principally because that was the dryest season recorded in the 100 years that weather records have been kept in St. Paul.

In 1895 Green carried out a series of experiments on early and late varieties of potatoes, using a 5-5-50 Bordeaux mixture. For some reason the yields he obtained that year were

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in general smaller on the sprayed plots than on the unsprayed, so that he concluded finally that it was very doubtful

if it paid to use the Bordeaux mixture.

This uncertainty as to the value of spraying is still felt by the majority of potato growers in Minnesota. One principal reason for this uncertainty is the fact that late blight is the exception rather than the rule, and the value of spraying is not evident to the growers, since a good crop of potatoes ordinarily develops if the Colorado beetle is held in check. Potato growing has largely been extensive, and the time and facilities for spraying have not been readily available. With the coming of more intensive potato culture, more interest is being shown in the prospective use of Bordeaux mixture.

Mr. A. R. Kohler performed potato spraying experiments at University Farm, St. Paul, in 1908, 1909, 1910, and 1911. He has published results covering the first two years of this work. From 1910 until the present time spraying experiments have been performed by the Section of Plant Pathology. The results of the work from 1908 to date are summarized in Table II.

These results indicate clearly that it pays, on the average, to spray potatoes

somewhat affected by the tendency of the potato to "run out" when grown in this soil. The results given, however, were obtained in the absence of late blight. No one questions the value of spraying when late blight occurs, and the yields obtained at University Farm show that the "insurance paid for itself" even in the absence of this disease.

Mr. T. M. McCall has reported considerable increases from the use of Bordeaux mixture in the absence of late blight, at the Crookston Substation, in Northwestern Minnesota.

TABLE I.—Tabular statement of the results from the use of insecticides, etc.

Name of Insecticide.	Yield 100 ft. of row, in pounds	Yield calculated for an acre in pounds.	Yield per acre in bushels.
Paris green.....	143	20,735	345
London purple.....	143	20,735	345
London purple and Paris green mixed.....	144	20,880	348
Gironde mixture (sulphate copper and lime).....	186	26,970	449
Peroxide of Silicates.....	121	17,545	292
Slug shot.....	101	14,645	246
Eau Celeste.....	106	15,370	256
*Kerosene emulsion.....	74	-----	-----

* Vines badly burned by the emulsion being used of too great strength.

with Bordeaux mixture. Unfortunately the soil at University Farm is not characteristic of the state, and the yields are



Spraying draws a sharp line of demarcation. This picture shows a portion of "spray plot" at University farm. Right half of picture, early Ohio variety sprayed with a 5:5:50 Bordeaux mixture; left, same variety sprayed with a 2:2:50 mixture. The plants remained green longer when sprayed with 5:5:50 Bordeaux than when sprayed with a weak solution or unsprayed.

While Minnesota potato growers in general have not consistently used Bordeaux mixture, certain men have tested it out rather thoroughly. The following is Mr. Floyd Riggs' experience, at Bertha, Minnesota:

"I have used Bordeaux mixture quite extensively for the spraying of Early Ohios for the past three years and have had very good success with it. In 1917 I had in 15 to 18 acres and they yielded 3,000 bushels and a little better. That is the year I made a comparative spraying on 4 rows. The rows that I did not spray could not resist the intense heat, and consequently I only received about two-thirds as many as I did from 4 of the rows that I sprayed." In 1918 Mr. Riggs obtained about 150 bushels per acre, a considerably greater yield than that of unsprayed fields in the vicinity.

We feel justified in recommending the use of Bordeaux mixture, about 5-5-50 strength, for Minnesota. Protection is thereby afforded against a possible recurrence of late blight. By reducing early blight and tipburn, and probably by repelling certain insects, the yield may be expected to be increased sufficiently to make spraying pay well. Unless late blight occurs or threatens, three or four sprayings at about ten days or two weeks intervals beginning when the plants are about ten inches high, will probably prove sufficient.

TABLE II.—Average gain or loss in yield as a result of spraying potatoes with 5-5-50 Bordeaux mixture, University Farm, St. Paul.

Year	Variety Sprayed	Gain or loss (-) of sprayed plots over unsprayed, per acre.
1908	Sir Walter Raleigh	Bushels 10.6
1909	Sir Walter Raleigh Early Ohio	16.8 4.5
1910	Sir Walter Raleigh Early Ohio	35.8 37.2
1911	Late Varieties Early Varieties	67.7 19.9
1912	Sir Walter Raleigh Early Ohio	-20.0 -17.3
1913	Rural New Yorker Early Ohio	-18.7 -48.0
1914	Rural New Yorker Early Ohio	113.3 29.3
1916	Rural New Yorker Early Ohio	29.0 16.3
1917	Rural New Yorker Early Ohio	33.7 48.4
1918	Rural New Yorker Early Ohio	92.0 87.5

Vegetable Investigations Being Conducted by the Minnesota State Experiment Station.

PROF. RICHARD WELLINGTON, UNIVERSITY FARM, ST. PAUL.

The first point which I wish to bring out, as it may not be fully understood by all those who live at a distance from the University Farm, is that the vegetable work is not carried out alone in any one division of the Agricultural Experiment Station, but in many divisions. This does not mean that the work is duplicated, but that different phases of the vegetable work are attacked by various people or so-called specialists. For example, the entomologists' work on the insects that destroy or injure our vegetable crops; the plant disease men, or plant pathologists, as they call themselves, work on the diseases which attack the plants; the soil men study the effects of fertilizers and their reaction on the various vegetables grown in different soils, and the horticulturists on the culture and improvement of varieties. As a matter of fact, the horticulturist is supposed to be posted on most of the practical phases which influence the productiveness and the growing of crops to perfection, but, like the rest of humanity, he oftentimes "does not know it all." In some institutions the marketing problems have been tackled, but Minnesota has done little in this line, so far as vegetables are concerned.

In addition to the work done by the University Farm, investigational work on vegetables is carried on by the sub-stations and demonstration farms at Duluth, Grand Rapids, Crookston, Morris and Waseca. Their work has naturally been more or less of a preliminary nature, such as testing out the best varieties for their respective localities, and co-operating with the central station in its potato projects.

To those of you who are acquainted with the conditions in the northern part of the state it is not necessary to call attention to the future possibilities of vegetable growing in that section. Lettuce, cauliflower, root crops and other cool weather loving crops grow to perfection in that region, and the limitation of their production is dependent simply upon markets, labor and capital. The sub-stations fully appreciate the needs in their sections of the state, and already Crookston has a good horticulturist to push the work in the Red River Valley, and the Grand Rapids and the Duluth stations are hoping to obtain similar men for their respective localities.

Mr. Thompson, of the Duluth Demonstration Farm, in co-operation with the Horticultural Division of the University Farm, is launching a project to determine whether it is possible by proper rotation of crops and by plowing under green cover crops to maintain the fertility of the soil in his locality. Similar experiments should be carried on in the various market garden soils around the Twin Cities, but unfortunately no such land is available at the present time. When manure cannot be secured the experiment station should be in a position to recommend methods for maintaining the fertility of the soil.

Statements secured from the Botanical and Entomological Divisions at the University Farm, which are carrying on vegetable investigational work, are as follows:

WORK OF THE DIVISION OF ENTOMOLOGY IN THE CONTROL OF VEGETABLE
INSECTS.

S. A. GRAHAM, U. FARM.

During the past year the work of the Division of Entomology on the control of vegetable insects has been concentrated almost entirely upon potato insects. An effort has been made to determine the insecticides best suited for potato spraying from the standpoint of both effectiveness and cost.

In brief, the results of the season's work show:

1. Under ideal conditions, paris green, lead arsenate, zinc arsenate and calcium arsenate are equally effective in controlling the potato beetle.

2. The sticking power of these insecticides is in the following ratio:

If paris green, 1.

If zinc arsenate, 50.

If lead arsenate, 62.

If calcium arsenate, 74.

3. Calcium arsenate is cheaper than any other of the arsenicals studied and contains a higher percentage of arsenic than lead arsenate and an amount equal to or greater than that of zinc arsenate.

4. All things considered, it seems that calcium arsenate is the most desirable of the arsenicals studied for use on potatoes.

Experiments in the control of leaf hoppers on potatoes indicate that nicofume 1-500, to which has been added one pound of soap to each 50 gallons of liquid, is effective, provided the insects

are hit with the spray. The question of leaf hopper control, therefore, resolves itself into the development of effective methods of application.

The results of this work on the control of potato insects will appear shortly in the report of the State Entomologist.

Other vegetable insect problems which have received considerable attention in the past few years, some of which were dropped for the period of the war, are listed as follows:

1. Greenhouse fumigation experiments.
2. General problems on the action of insecticides, which are being carried on by Mr. Moore, and which have already given much valuable information which can profitably be applied to the practical control of pests.
3. White grub control.
4. Onion and cabbage maggot control.
5. Wireworm control.
6. Cutworm control.

Information upon these subjects and many others is available upon request.

WORK ON VEGETABLE DISEASES AT UNIVERSITY FARM.

G. R. BISBY, U. FARM.

The Section of Plant Pathology is anxious to be of service to vegetable growers insofar as time and funds permit. University Farm is geographically favorably located to work with Twin City vegetable growers, and we desire to have their vegetable disease problems put up to us.

The work done or planned on the different crops is partially summarized below. Bulletin 153 on "Fruit and Vegetable Diseases and Their Control," includes much of the work done in the past.

Potatoes.—The various diseases have been studied, and treatment of seed tubers, the use of seed plots and spraying for leaf diseases are recommended. Considerable of these data have been published in Bulletin 158. Further work is being done with potato diseases.

Bean.—Blight and anthracnose have been studied as to possible methods of control. Spraying has not been found to pay, but sanitary precautions and the use of a seed plot for selected seed are recommended.

Cabbage.—Minnesota has in the past escaped serious trouble with certain cabbage diseases, although some trouble has

recently been experienced. It is planned to work particularly with black rot and blackleg, and to attempt to prevent wilt from becoming a serious factor.

Celery.—Co-operative experiments have demonstrated the value of spraying for leaf blights.

Cucumber.—Considerable work has been done with diseases of cucumbers. Wilt is sometimes serious; diseased plants should be removed and burned when found. Spraying and general sanitary precautions should be used for certain other cucumber and melon diseases. Cucumber nubbin has lately been serious in



Test of Chinese cabbage strains made at University Farm in 1918. Certain strains were excellent and others worthless.

many cases, and care must be exercised to avoid this disease if possible. Further work is planned by the Section of Plant Pathology.

Tomato.—Spraying has been demonstrated to be a control measure for leaf spot. Tomato mosaic has assumed considerable importance, and caution is required to avoid its spread. This disease will be considered in further experiments.

Other vegetable crops often suffer from diseases, and rots in storage or transportation are important with various vegetables.

In the Horticultural Division, a few projects are being carried out, and their scope is simply limited by land and resources at hand. One of the most fundamental projects under way is to determine whether certain varieties can be improved by selec-

A Member: Did your cabbage freeze last spring?

Mr. Wilkus: I didn't have any frozen, no; but there were a number of gardeners that had them frozen last spring. The main point is to get your plants hard.

A Member: What do you do for the worms?

Mr. Wilkus: I use Bordeaux mixture and paris green and lime.

A Member: How often do you put it on?

Mr. Wilkus: I put it on after every rain until all signs of the worms are past.

A Member: How late would it do to put the paris green on?

Mr. Wilkus: I put it on as long as I see any worms, I do not pay any attention to that. Understand I put on lime, Bordeaux mixture and paris green. I don't use a great deal of paris green, in fact, so little that there is no danger.

A Member: Put it on wet?

Mr. Wilkus: No, dry; got to be dry.

Mr. Hoyt: When the leaves are damp?

Mr. Wilkus: When the leaves are damp. You understand the cabbage worm works in down around the stem mostly and gets in from the head underneath. Other insects get some of the outside leaves but the one that does the most damage is the one down in. I find that the greatest damage is done in the hotbeds with maggots; in certain districts where the soil is rich and lots of stable manure is used there are lots of maggots. I don't know of any particular remedy for the maggots; the only thing is to not to use fresh manure on the cabbage land.

Mr. Clausen: Is there any preventive for the long-stemmed Holland cabbage?

Mr. Wilkus: That is in the varieties. You want to buy the short-stem Holland cabbage. There is no use of growing those long, we have good short ones.

A Member: A remedy for the maggots is a solution of tobacco water.

Mr. Wilkus: That is all right in a small garden but in a commercial way you couldn't do that.

A Member: You could buy two or three pounds of tobacco and use that.

A Member: I was in Plainview a few days ago, and they are raising a great many car-loads of cabbage there. They had been shipping plants to Alaska for their early cabbage. This man got \$35.00 a ton for his early cabbage, so he would realize \$300 from an acre. He said the plants they shipped to Alaska for export are the ones that looked like a lot of brush. They looked as though they were perfectly dead, just thrown into a heap and sent up here, and he said they set them up and there came a great freeze after they set them out and the plants survived and gave them a good crop. I wondered if we were not making a mistake in not patronizing our southern neighbors.

Mr. Wilkus: I have some frost-proof cabbages, but I find it is better to grow your own. Start them early and harden them and they will be all right.

Progress in 1918 in Controlling Potato Diseases.

G. R. BISBY, EXPERIMENT STATION, UNIVERSITY OF MINNESOTA.

Since potatoes were first planted in Minnesota there has never been a year when the crop did not suffer from diseases, and we can see no prospect for a future in which potatoes will not have them to contend with. The loss from most of these diseases can be reduced, however, by the application of certain measures and principles that have been worked out, and it is the purpose of this paper to report on the progress made in the fight against potato diseases.



FIGURE 1. Effect of Bordeaux mixture on yield. Crop in each case from two square rods of Rural New Yorker variety. No. 1 not sprayed with Bordeaux mixture; yield 61 pounds, tubers rather small. Those in front are diseased with black scurf. No. 2 sprayed three times with 5:5:50 Bordeaux mixture. Yield 106 pounds, tubers large.

Every cultivated plant has its diseases. The potato suffers from a large number of diseases caused by fungi, by bacteria, by the weather, or by an innate tendency of the plant to degenerate. With modern international transportation, there is no potato disease in the most remote corner of the globe that is not liable to be introduced, to add to the difficulties of growing the crop here in the United States and sooner or later in Minnesota. Only this autumn the dreaded wart disease, one of the worst of the potato diseases known to Europe, was found in Pennsylvania. We will hope it may be stamped out before it spreads into the larger potato growing districts and into the channels of trade. "Eternal vigilance" is necessary in order to avoid serious losses from diseases. The plant pathologist seeks to prevent the intro-

duction of new diseases, and to work out methods by which the loss from diseases already present may be kept at the minimum.

When the number and seriousness of potato diseases is recognized, various methods may be utilized to prevent these diseases and thus to increase the crop. These measures are those involved in better growing practices and more intensive and careful methods in potato production. There will probably not be again such an extreme shortage of help, and the signs point to a new era in horticulture in which the best methods will be intelligently applied.



FIGURE 2. Effect of seed treatment on yield. Each number represents the crop from one square rod, those in front being diseased with black scurf, those in the rear are healthy. No. 1, seed treated with corrosive sublimate solution for two hours. No. 2, seed treated with copper sulphate solution for two hours. No. 3, seed treated with formaldehyde solution for two hours. No. 4, no treatment. Formaldehyde solution is effective against scab, but not against black scurf (*Rizoctonia*).

Seed selection, seed treatment, crop rotation, proper soil conditions, careful cultivation and handling of the crop, roguing, spraying, grading, improved methods of marketing, and other measures, suggest themselves as methods to be considered in growing better potatoes. I will limit myself to a few points which have to do more directly with potato diseases, and by means of which the production may be increased. I will mention only measures which have been tried out in the field at University Farm. I assume you are interested in the experimental data obtained from year to year at the Experiment Station at University Farm, and we are always anxious to give this society and the public the benefit of any methods of plant disease control which may have been demonstrated.

During the past year we have continued spraying experiments with Bordeaux mixture. This is the tenth year these experiments have been carried on by the Section of Plant Pathology, and these experiments really continue those started by the late Professor S. B. Green, in 1888. Last year I presented figures showing a marked increase in yield under the conditions such as exist at University Farm, and the results this year show similar results. We are satisfied that spraying with Bordeaux mixture will pay handsomely on certain types of soil, and should be tried if potatoes have not yielded satisfactorily without the application of Bordeaux mixture. This increase occurs even in the absence of late blight. Under more favorable conditions for the potato crop spraying may not produce such increases in yield. We are now writing up the results of spraying potatoes with Bordeaux mixture, and the information will be available to you later in a bulletin. Figure 1 shows a comparative yield from sprayed and unsprayed plots at University Farm.

Our treatment plots this year gave the best results from the use of corrosive sublimate as a disinfectant for diseased tubers. Table 1 gives the results of different treatments against black scurf on the Early Ohio variety, and Figure 2 the effect on the yield of Rural New Yorkers.

Table 1. Effect of different disinfectants for different lengths of time upon the per cent of black scurf upon the crop. Early Ohio variety.

Character of tubers planted	Treatment	Time hours	Per cent of black scurf on progeny
Clean	None		7.2*
Affected with black scurf.	Corrosive sublimate	2	15.5
	Copper sulphate	2	24.7
	Formaldehyde	2	22.9
	Copper sulphate	1	31.3
	Corrosive sublimate	1½	32.8
	Formaldehyde	1½	35.3
	Lime sulfur 1-30	2	47.1
	Copper sulphate	1½	49.7
	Lime sulfur	2	56.1
	None .....	..	61.1

*Average of 22 different plots.

These results show the value of planting perfectly clean seed if it can be obtained, and of disinfection if clean seed can not

be secured. Copper sulphate solution (3 pounds to 50 gallons of water) has proved valuable in trials over four years.

The rotation plots we are carrying on from year to year show that disease organisms increase in the soil when the crop is grown continuously on the same field. Rotation is an obvious method of increasing production through the avoidance of disease.

Results secured in 1918 show further the value of removing weak and "run out" plants from the stock to be saved for seed. These weak plants produce very poor progeny.

Finally I should like to speak a word for more careful handling of potatoes after harvest. One of the largest losses to the crop is that from rots during storage and transportation. The organisms causing rot gain entrance especially through wounds in the tubers, and wounds are brought about particularly by careless handling. The storage bins should also be cleaned and disinfected before potatoes are introduced.

Now that conditions are approaching normal, we hope to carry on considerable work on diseases affecting horticultural crops. I can not overemphasize the fact that we desire only co-operation from those whose business is to produce these crops.

CARBON DISULPHID EFFECTIVE IN KILLING WOOLLY APHIS ON ROOTS.—Carbon disulphid, in solution at the rate of one-half ounce to 4 gallons of water and applied at the rate of three-fourths gallon a square foot of soil, will control the root form of the woolly apple aphid and without injury to the trees under suitable conditions, says the United States Department of Agriculture, in Bulletin 730, recently published.

The solution is prepared by pouring the carbon disulphid into the water and agitating the mixture vigorously. When applied on the soil around a tree the liquid penetrates into the ground and the poison gas given off by the chemical kills the pest. Every square foot of infested soil should be subjected to the action of the solution in order to insure complete control. This may be accomplished by pouring the liquid in a shallow basin made in the soil around the tree.

In orchard practice, where many trees are to be treated, the solution is best applied by using a powder spraying outfit and two auxiliary tanks. The advantages of this method, according to the bulletin, are the even diffusion of the liquid and complete aphid mortality in the soil area treated and the safety with which the disulphid can be used. The disadvantages of the method are: the huge amounts of water required, with consequent high cost of labor; the difficulty on any but level ground of preparing basins with level floors, thus insuring the proper distribution of the liquid over the area to be treated; and the wide area of infested roots on older trees, every square foot of which must be treated with the liquid. This last condition precludes the use of carbon disulphid except on small trees with restricted root areas.

Sodium cyanid, kerosene emulsion, and deep planting of trees were other measures of control investigated, but they are not recommended by the department.—Weekly News Letter.

Trees for Street, for Shelter and for the Lawn.

DISCUSSION LED BY GEORGE H. WHITING, YANKTON, S. D.

To start this discussion I have made a short list of the most desirable varieties. I have not given all the varieties that are desirable, but the most common, and most used varieties that most of you know of. I have classified them somewhat; in the shade and street trees I have tried to put them as near as I could in the relative position that I think they are entitled to.

I will give the best first. White elm, green ash, hackberry, soft maple, wild black cherry, honey locust, basswood or linden, catalpa (*speciosa*), hard maple, Norway maple, box elder and Carolina poplar. This last named isn't really a desirable shade or street tree only in places where you want a large tree. I notice there are some avenues down in Chicago—I think the Jackson Park Boulevard has a row of Carolina poplars on each side. They are planted a long distance apart. There is quite a broad parking so they have plenty of room. Where one wants a very large tree and wants it quick, the Carolina poplar would be desirable, but we do not consider it a valuable tree for a long lived tree, or a place where you want a tree for a long time.

I presume there isn't any other tree that is so generally used, and generally desirable over the whole United States, as the American white elm. It is a good tree for the street and it is long-lived. Some of the grand old trees back on the Boston Commons are the American white elm. They are old, old trees, a hundred or perhaps two hundred years old.

The next variety that I have named is the western white ash or green ash, a variety that has not been used as much in the past for a shade tree. It is the general opinion that an ash is a very slow grower and some object to the ash on account of its tendency to be attacked by borers. My experience has been, however, that the borers do not attack the ash tree very severely where they are reasonably thrifty and doing well. They generally attack a tree that is in poor condition, or is making a very slow growth. The green ash is a native away out west in the Dakotas and out in Colorado, Montana and Wyoming, and they are standing adverse conditions, they are extremely hardy as to cold and stand dry conditions pretty well. Of course, they do not grow so fast when they are in the dry belt, they are a rather slow grower, but where the ash has a chance to do anything it doesn't grow so slow and it is a strong tree. It is a rather

to a point where the grain crop is likely to lodge. This makes it desirable to modify the rotation, and some growers have found that by changing to a four-year rotation and growing two cultivated crops, following the clover, one crop of corn, and one of potatoes, they have been able to get excellent crops and check somewhat the tendency of the grain to lodge. It has not been demonstrated yet which is the better order of growing these two cultivated crops; that is, which one should be grown first. It is the writer's judgment that the better plan is to grow the potatoes on the clover sod, then follow this with a crop of corn, for the reason that if the corn is grown first the corn stubble may cause some trouble in the cultivation of the field for potatoes.

Five-Year Rotation

Another rotation that has worked out splendidly at University Farm is a five-year rotation, consisting of crops in the following order: wheat, meadow, pasture, oats and corn. For the last twenty years this rotation has given yields of approximately twice the average yields in the State of Minnesota. In this rotation the land gets eight loads of manure per acre once every five years. This manure is applied to the corn crop. This rotation would, of course, work out approximately the same way if potatoes were planted in place of corn, or what would work out desirably on a great many farms would be to divide up the field in cultivated crops between corn and potatoes. Such a rotation, of course, provides for rotation pasture. On many farms this is desirable.

THE TOLL OF POTATO DISEASES

G. R. BISBY AND F. JEAN MACINNES

Each year the Section of Plant Pathology at University Farm keeps as accurate a record as is possible of the losses from plant diseases. This article lists the losses from potato diseases for the season of 1918 and explains how the figures given were obtained.

The Bureau of Markets of the United States Department of Agriculture has inspectors stationed at various terminal markets, who inspect and report on the condition of potatoes being shipped into these various markets. Table 1 gives the results of these reports for Minnesota. To explain the figures presented in this table, we may examine the first disease, scab. The inspectors sent in 150 reports giving in each case a certain per cent of scab. The average of these 150 reports gave 7.1 per cent as the average when the disease was reported. A total of 344 reports was received, however, 194 of which did not mention scab, indicating that it was absent, or present only in rather negli-

gible quantities. This gives an average of 3.1 per cent of scab for all reports. Our observations through the state had shown that the disease was generally distributed. Obviously however, 3 per cent of scab does not mean the loss of 3 per cent of the crop. An estimate of 1 per cent is, however, conservative. Since the crop harvested in Minnesota was about 30,000,000 bushels, scab caused a loss of about 300,000 bushels. In 1918 potatoes brought about 50 cents per bushel or more to the grower. The loss was easily \$150,000.

In addition to the reports sent in by the Bureau of Markets, we keep a careful record of information obtained when traveling in various parts of the state, and of various reports that come in. These data are also drawn upon in figuring the losses.

Late blight was of limited occurrence in 1918, though it has been very serious in some years. Dry rot of the tubers was,

however, very common and serious. Nearly seven per cent of the crop shipped out of the state showed the disease. Since dry rot usually destroys the tuber for cooking or seed purposes, and since many rotted tubers would be sorted out before shipping, a loss of five per cent is doubtless conservative.

The loss from the other diseases was similarly figured. Adding the losses in Tables I and II, we find that 17 per cent of the crop was lost, which means, figuring on the basis of thirty million bushels, a loss of 5,100,000 bushels, worth easily \$2,550,-

000. A more accurate method of figuring the loss would be that of considering 17 per cent of the crop destroyed, and therefore, only 83 per cent of a crop was produced. If 30,000,000 bushels is 83 per cent, 100 per cent, or a crop without diseases, would be over 36,100,000 bushels. Few will doubt that a crop absolutely free from disease would have been greater than 36,000,000 bushels in Minnesota in 1918.

The figures for 1919 are not yet prepared, but will doubtless be similar to those of 1918.

Table I. Storage diseases of tubers as found in transportation

Disease	No. reports having percentage of damage indicated	Ave. percentage of disease on these reports	Total No. reports on tuber diseases	Average percentage of disease	Relative prevalence in state	Estimated loss to growers in Minnesota		
						Percentage	Bushels	Value at 50c per bu.
Scab.....	150	7.1	344	3.1	General	1.0	300,000	\$150,000
Late blight rot.....	16	16.0	344	.7	South & S. E. only	0.3	90,000	45,000
Dry rot...	201	11.5	344	6.7	General	5.0	1500,000	750,000
Soft rot...	43	6.7	344	.9	General	1.0	300,000	150,000
Black scurf	20	5.0	344	0.3	General	See dry stem rot		
Frost.....	6	16.0	344	0.3	Rare	Trace		
Total.....						7.3	2,190,000	\$1,095,000

Table II. Field Losses

Disease	Relative prevalence	Loss in bushels	Loss at 50c per bu.	Estimated percentage of crop lost
Early bright.....	Rather general	300,000	\$150,000	1.0
Black leg.....	Cent. & N. W	900,000	450,000	3.0
Tipburn.....	General	600,000	300,000	2.0
Mosaic and dwarf.....	Gen. on Triumph especially	60,000	30,000	0.2
Dry stem rot.....	General	600,000	300,000	2.0
Wilt.....	Cent. & West	450,000	225,000	1.5
Leaf roll.....	Not common	....	....	Trace
Total.....		2,910,000	\$1,455,000	9.7

\$2,550,000 LOST!

THROUGH

Potato Diseases

IN

Minnesota Alone

IN 1918

“Some” tax on the Industry!
And most of it might have
been saved.

POTATO DISEASES

G. R. BISBY

The potato crop of Minnesota and of other states is reduced by a considerable percentage every year from the diseases which affect it. If these diseases were not preventable, if they were brought about only by weather or other unavoidable conditions, it would be useless to discuss them. The majority of the growers in the state realize, however, that most of these diseases are preventable, at least to a large extent. It is the purpose of this article to call attention to the seriousness of potato diseases, to point out the distinguishing characters of the various diseases, and to discuss briefly certain control measures.

About five million bushels of potatoes were lost from diseases in Minnesota in 1918 according to our best estimates, as explained in another page. These losses are to a considerable extent perpetuated through succeeding years when diseased stock is planted, especially if seed disinfection, crop rotation and other good practices are not employed. Those who have attempted to grow certified seed have had their attention particularly called to the seriousness of potato diseases.

The following key gives brief distinguishing characters for the most serious diseases which occur in Minnesota:

Key to Minnesota Potato Diseases

Leaf Diseases:

Leaves Only Affected:

Diseased spots on any portion of leaf, often with concentric markings. 1 Early Blight.

Diseased spots on tip or margin of leaf. 2 Tipburn.

Veins affected most seriously. 2a Hopperburn.

Veins least affected. 2b Sunscald.

Leaves, Tubers and Often Stems, Affected:

Spots on leaf watersoaked and

mouldy beneath when wet, irregular. 3 Late blight.

Leaves Mottled, Curled or Rolled, Whole Plant Affected: See Mosaic.

Mosaic and Similar Diseases, Affecting the Whole Plant, but Manifest on Foliage Only:

Leaves mottled with darker green and lighter green or yellowish, often crinkled more or less. 4 Mosaic.

Leaves much crinkled, more or less mottled, plant dwarfed. 5 Mosaic Dwarf.

Leaves, especially lower, rolled, crisp; plant unthrifty. 6 Leaf Roll

Stem Diseases, Affecting Tubers Also:

Stems rotted throughout, black and slimy at first; tubers often rotted with a slimy soft rot. 7 Blackleg.

Stems rotted in definite areas, brown, not slimy (dry stem rot); tubers affected with black masses on surface (black scurf). 8 Rhizoctonia Disease.

Stems affected and browned internally, especially in sap tubes, sometimes whole lower stem browned; tubers with brown ring or a rot at stem end. 9 Wilt.

Tuber Diseases:

Tubers Affected Internally:

Hollow area near center. 10 Hollow Heart.

Black area inside tuber. 11 Black Heart.

Brown spots or lines inside tubers. 12 Net necrosis.

Brown ring or rot at stem end: See No. 9. 13 Brown Ring Discoloration.

Tubers Affected Only Externally:

Roundish corky spots without torn epidermis. 14 Common Scab.

Roundish powdery spots, smaller than preceding, epidermis torn. 15 Powdery Scab.

Black dirt-like masses on surface; See No. 8. 16 Black Scurf.

Silvery patches on skin of tuber. 17
Silver Scurf.

Tubers Affected Internally and Externally:

Wart-like swellings from eyes and elsewhere, roots often affected. 18
Black Wart.

Tubers soft, blackened inside, rather sweet. 19
Frost Injury.

Tubers green externally and somewhat internally. 20
Sunburn.

Tubers rotted, dry or wet. See 3 and 7. 21
Storage Rots.

Since there is not space for a detailed discussion of all the various potato diseases, methods of preventing or avoiding certain of them will be particularly discussed. Rather specific control measures for certain diseases or groups of diseases will be first considered, followed by some general methods for lessening the losses from potato diseases.

Diseases affecting the leaf (excepting the mosaic type of diseases) may be largely prevented by spraying with Bordeaux mixture. The manufacture and use of this preparation is described below. While Bordeaux mixture is employed particularly against late blight, it is also efficacious against tipburn and early blight, and when correctly used can be expected in any year to increase yields sufficiently to more than pay for its use. Late blight is fortunately of rather uncommon occurrence in Minnesota, and need be expected only about once in five years on the average. When it does appear, however, it may develop into an epidemic that will ruin a field that has not been sprayed. Early blight occurs to greater or lesser extent every year over most of the state. This disease is less serious on sprayed plants. The tipburn condition is brought about either by leaf hoppers, which affect the veins of the leaf and cause a death of the veins and adjacent tissue, or by the sun and by dryness, in which case the edges and tips turn brown, the veins being least affected. The application of Bordeaux mixture serves to repel the leaf hoppers, and to lessen the amount of dry-

ing of the leaves. Bordeaux mixture should be used more by those who are desirous of growing better potatoes and increasing their yields. Paris Green or lead arsenate may be combined with the Bordeaux mixture to kill insects.

The mosaic disease has attracted much attention the past year, particularly by growers of Bliss Triumph, since it has been found that almost all lots of the Triumph variety in the state are affected with this disease. Other varieties, such as the Green Mountain, have also been found infected to a slight extent. Since this disease has not been emphasized before as serious in this state, it is here discussed somewhat fully.

This disease was first described in 1914 by Orton, of the United States Department of Agriculture. He had observed it in Germany and in Maine; an examination by Dr. Orton in Minnesota in 1912 and 1913 did not reveal the disease, although the Triumph variety was probably not examined particularly. In the five years that have elapsed since Orton described the disease, its importance has become increasingly evident. Recently workers in the United States Department of Agriculture have shown that the disease is spread from plant to plant by certain insects, although the symptoms are slow to appear, and often do not become evident until the following year, when tubers from the plants which have been infected are planted.

The disease is manifested, as the name indicates, by a mottled appearance of the leaf. This mottling is usually not conspicuous, and often is not evident except when the plants are young. The leaves show areas lighter green in color as contrasted with other areas on the same leaves which are normal in color, and there is also usually a crinkling of the leaf. Figures 1 and 2, which contrast healthy and diseased plants, give a good idea of the general appearance of affected plants. While the effect on the plant in mild cases of mosaic is often not severe, the disease may increase from year to year

Let Us Spray

It is the only way to

save

Potatoes

from many of the diseases to
which they are heir.

*Read what the Potato Doctor
has to say.*

until extremely dwarfed and low-yielding plants are produced as is illustrated in Figure 3. Figure 4 shows the yield from the square rod illustrated in Figure 3, compared with the yield from a square rod of healthy Early Ohios.

The mosaic disease may not affect the yield greatly in Minnesota in cases in which the infection is mild. There are cases that have come to our attention in which practically every plant in a field of Triumphs showed mild mosaic; and yet the plants yielded at the rate of 300 bushels per acre. There is always danger, however, of the disease producing dwarfed, low-yielding plants even under the favorable conditions of northern Minnesota. When even the highest yielding strains of the Triumph variety which show the disease are sent into the South for seed, moreover, the disease seems to attack the resulting plants seriously, and the yield is greatly reduced. It is for this latter reason particularly that the importance of the disease is emphasized.

While the tubers from affected plants look perfectly normal except that they are often smaller, they nevertheless, carry the disease, and plants grown from these tubers show the mosaic. There is no known way of detecting the disease in the tubers, or of destroying the infection if present.

The disease probably spreads from plant to plant in the field by being carried by insects. The cause of the disease is apparently of the "virus" nature, and cannot be seen even with a microscope.

No cure is known for the disease. The prevention of mosaic is difficult. If seed could be saved from a field in which all the plants were free from the disease, healthy plants would result. Such fields of Bliss Triumph are apparently rare, either in Minnesota or elsewhere in the United States. It is unsatisfactory to attempt to select tubers from healthy plants in a field which shows much of the disease, since the apparently healthy



FIG. 1. MOSAIC AND HEALTHY EARLY OHIO. EARLY STAGE, JULY 9, 1919.

plants may have been infected by insects coming upon them from diseased plants. Efforts are being made to secure a stock of healthy Bliss Triumphs for Minnesota, and to guard against serious infection of other varieties.

Leaf roll (Figure 5) is a disease probably similar in nature to mosaic, but apparently not common in the state. The lower leaves particularly show a rolling, and are crisp in texture. The whole plant has an appearance often spoken of as "staring," and produces a small yield. The disease is transmitted by the use of seed tubers from affected plants.

Of the stem diseases, blackleg may be lessened by using healthy seed tubers, and by seed treatment or disinfection as

described below which is of value in sterilizing the surface of the potatoes before planting. The *Rhizoctonia* disease (dry stem rot) is avoided to a considerable extent also by disinfection, which kills the fungus which occurs on the tuber as black scurf. Wilt may be largely avoided by rotation of crops and the provision of good growing conditions for the plants, and also by clipping off the stem end of seed tubers which may harbor the fungus.

The potato tubers suffer from a number of diseases. Hollow heart often occurs when certain varieties of potatoes grow to a large size. This condition can be prevented by planting the potatoes somewhat more closely together, or by growing varieties not susceptible to this

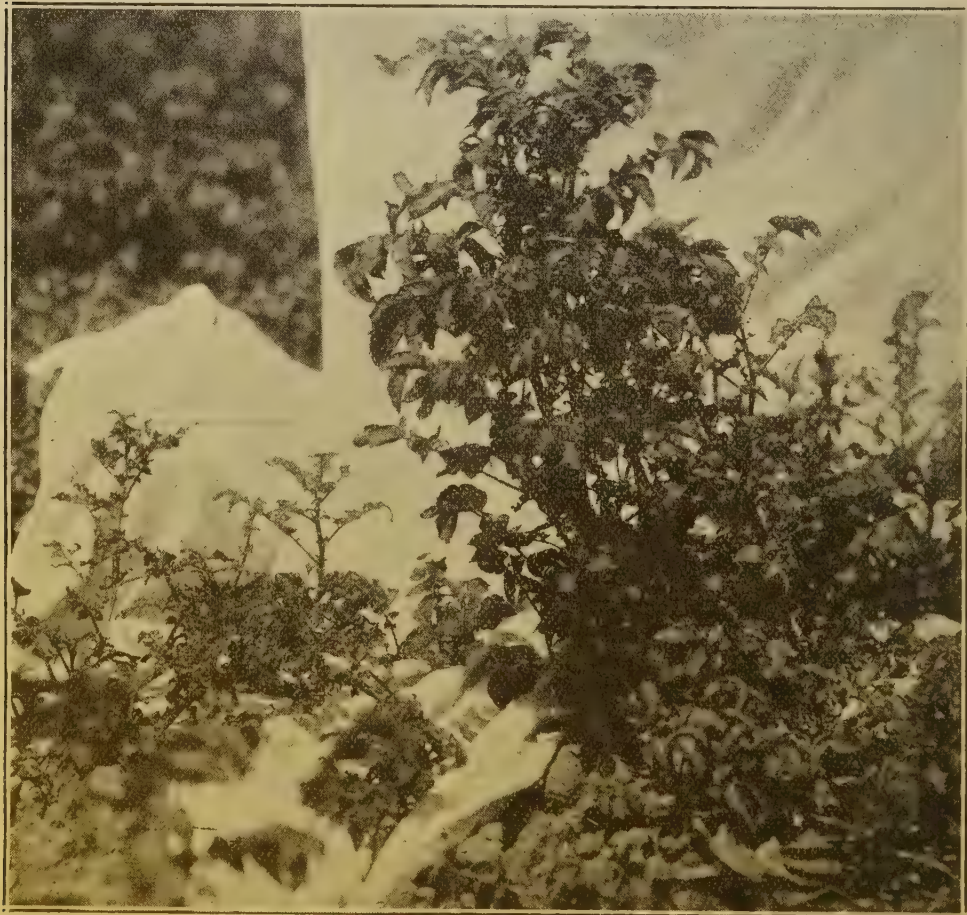


FIG. 2. MOSAIC AND HEALTHY EARLY OHIO PLANTS LATER STAGE. PHOTO JULY 28, 1919

condition.

Black heart is brought about as a result of heat in storage or transportation, or sometimes through absence of air in storage. Net necrosis is rather rarely found.

Common scab and black scurf on the tuber can be killed by corrosive sublimate solution, as described below. Formaldehyde solution kills the scab germs on the tuber, but not black scurf. It must be remembered with both these diseases that the germs of the disease are often in the soil. Treatment of the tubers is, however, a sanitary measure which lessens the liability of attack by these diseases.

Powdery scab occurs sometimes in northeastern Minnesota; infected tubers should be "treated" as for common scab before being planted. Silver scurf is of very little importance in this state. Black wart is discussed in another article in this Annual.

Storage rots cause a very heavy loss annually to Minnesota growers and shippers. This loss is due to a considerable extent to the careless way in which potatoes are usually handled. In many bins it is hard to find tubers which are not bruised or injured in some manner. Too often potatoes are handled like cobblestones. A bruised or injured potato is very liable to rot, since the broken skin allows rotting organisms to enter.

Storage bins or cellars should be thoroughly cleaned out, and should be disinfected, before potatoes are put in. Provision should be made for ventilation. The storage should be cool, as near 35 degrees Fahrenheit as it is possible to keep it.

Bordeaux mixture is made at the rate of about 5 pounds of copper sulphate (blue stone), 5 pounds of stone lime, and 50 gallons of water. Dissolve the copper sulphate in 25 gallons of water by hanging it in a coarse sack so that it just dips into the water in a wooden barrel. Do not use metal for copper sulphate solution. Slake the lime, and add water



FIG. 3. LAST STAGE OF MOSAIC PHOTO JULY 9, 1919

to make 25 gallons. Mix the two by pouring them together, and spray at once after mixing.

If large fields are to be sprayed, make stock solutions by dissolving one pound of blue stone in each gallon of water, make the lime mixture at the rate of one pound of lime per gallon of water. These stock solutions keep indefinitely if the water is not allowed to evaporate. When spraying, mix at the rate of 5 gallons of each mixture and 40 gallons of water, thus making 50 gallons.

Corrosive sublimate solution is made from 4 ounces of sublimate to each 30 gallons of water. If smaller quantities are wanted use one ounce to 7½ gallons of water, or in any proportion at the rate



FIG. 4. YIELD FROM 1 SQ. ROD OF MOSIAC PLANTS AND 1 SQ. ROD OF HEALTHY PLANTS.

of one part corrosive sublimate to 1,000 parts water. Soak the potatoes about $1\frac{1}{2}$ hours the first time used, $1\frac{3}{4}$ for the second lot of potatoes, 2 hours for the third and fourth lot, then throw the solution away and use a fresh lot of solution. Do not use metal containers, and remember that it is deadly poisonous.

Formaldehyde, if used, is made up at the rate of one pint to 30 gallons of water. For disinfecting bins, etc., about one pint to 10 gallons of water, or one pound copper sulphate to 10 gallons of water, is satisfactory.

Good agricultural practices, such as crop rotation, and selection, careful handling of the crop, etc., do much to lessen the damage from diseases. Many of these measures are discussed elsewhere in this publication. Vigorous strains of potatoes

should be grown, and all possible care taken to lessen the losses from diseases.



FIG. 5. LEAF ROLL. OBSERVE UPWARD ROLLING OF LEAVES.

THE POTATO WART DISEASE

J. J. CHRISTENSEN AND G. R. BISBY

Potato wart, which is usually considered the most serious and destructive disease attacking potatoes, has made its appearance in the United States. The disease is causing a very serious loss to potato growers and buyers in Ireland, England and other European countries. Losses in fields and gardens there often run as high as 50 to 80 per cent. It is not uncommon to have total failures due to this disease; in fact, there are places in Ireland and England where potato-growing has been given up as unprofitable due to this serious malady, known as potato wart.

History of the Disease

It is impossible to say where the disease originated. Potato wart was, however, described for the first time in 1896 by Schilberszky, of Hungary, but the disease was undoubtedly present some years before. As early as 1893 the disease was prevalent in England and it is believed to have existed in that country for at least forty years. Ireland reported the presence of potato wart in 1908, about the same time that it was reported in Scotland, Wales and Germany. One year later it was discovered in Newfoundland. In recent years the disease has made its appearance in Norway, Italy and France.

In 1910 the Federal Bureau of Plant Industry put out warnings as to the danger and seriousness of this disease. Attempts were at once made to establish an embargo against importation of potatoes from countries where potato wart was known to exist, but it was not until 1912 that such a quarantine was established. In the meantime over thirteen million bushels of potatoes had been imported.

In September, 1918, six years later, potato wart was discovered in Pennsylvania. After a thorough survey in the

Warts Destroy Potatoes--

from
50 to 80
per cent
sometimes
in
European
Countries

We do not want
them in
Minnesota

fall of 1918, by the United States Department of Agriculture, the wart disease was located in small gardens in twenty-seven towns and villages in Luzerne, Schuylkill and Carbon counties of Pennsylvania. The disease had evidently existed in these mining towns for a number of years as their potato crops had been ruined for three or four years previously. The people did not know the cause and attributed it to the soil and weather conditions. During 1919 new areas of infection have been found one hundred miles from those found last year. The disease also appeared in two localities in West Virginia.

Cause and Nature of Disease

The disease is caused by a parasite, one of the lower type of fungi (*Chrysophlyctis endobiotica*). The organism gains entrance usually through the tender eyes of the tuber. The fungus may also attack the stolons or roots or that portion of the stem proper below the ground. After infection has taken place the organism stimulates the host cells, and there results a spongy, warty outgrowth, somewhat like a cauliflower in appearance. The size of these outgrowths may vary from that of a spongy, warty protuberance the size of a pea to that of a large cauliflower-like mass large as, or larger than, the tuber itself. In severe cases of infection the potato may be completely surrounded by warty masses, so that the tuber loses all its true characteristics. These outgrowths are at first whitish, but gradually become brown and as the potato matures they eventually turn black. The Potato Wart is easily recognized except in its early stages but the disease can not be detected until the potatoes are dug since the growth of the vines does not appear to be seriously affected.

Danger of Disease

As the potato matures the warts decay and secondary rot sets in; and often affected hills are a total loss or when infected tubers are stored, rot often claims a

Wage War on Warts!

Burn or boil all warty potatoes dug and warty parings.

Feed no warty potatoes to livestock unless they have been boiled.

Rotate potatoes with other crops.

Plant no potatoes in infected soil for at least ten years.

Grow no potatoes in or around infected areas. You must have a government license to do so.

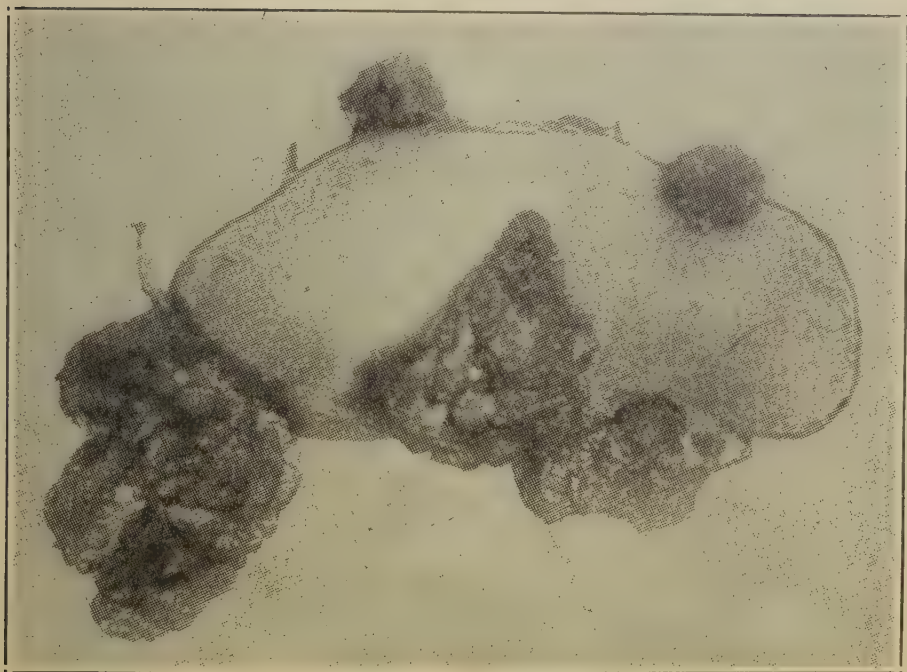


FIG. 1. WART ON POTATO TUBER

large percentage of tubers in a short time. Whenever these cauliflower-like protuberances decay millions of germs of the disease are released. These disease germs (spores) can live over winter in the soil; in fact, there is evidence that the buried spores in the soil, like seeds of certain higher plants, may remain inactive, but alive for eight years or more.

How Spread

Tubers may appear perfectly healthy yet they may harbor the fungus, if they have been grown in infected soil or have been in contact with warty potatoes while in storage. It is now believed that new localities are usually infected in this manner. Of course, the disease can be spread by planting diseased tubers. The disease can also be distributed by means of agricultural implements used to cultivate infected fields; by particles of dirt adhering to feet of men and animals; or by transferring small particles of earth along with root crops. If drainage conditions

are suitable the organism may be carried long distances by means of water. It has also been shown that the spores survive passage through the digestive tract of animals; so that if the diseased tubers are fed to animals without being boiled infection can take place through the use of manure. Peelings thrown in garbage may be a source of infection also.

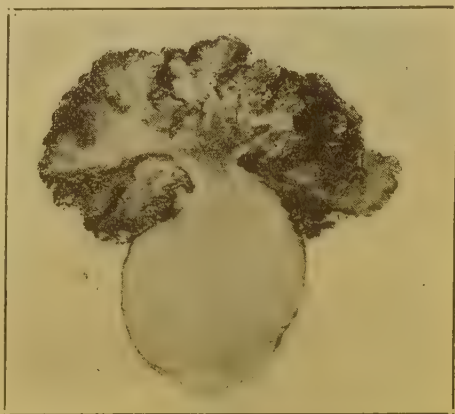


FIG. 2. CROSS SECTION THROUGH WARTY TUBER



FIG. 3. EFFECTS ON UNDERGROUND PARTS OF POTATO PLANTS. FIGURES 1, 2 AND 3 BY COURTESY OF THE PLANT DISEASE SURVEY OFFICE, U. S. D. A.

Prevention

1. All warty potatoes dug should be burned or boiled. The same holds true for parings.

2. Do not feed live stock warty potatoes unless they have been boiled.

3. Rotate with other crops. Do not plant potatoes on infected soil for at least ten years.

4. Some varieties seem to be resistant.

5. Strict quarantine (the growing of potatoes in and around infected areas is not permissible without a license issued by the federal government).

Survey in Minnesota

The United States Department of Agriculture fully realized the seriousness and destructiveness of this new disease. This led the Department to co-operate with the states in locating and stamping out this destructive disease of potato before it gained too strong a foothold.

In Minnesota the survey was undertaken in co-operation with the Plant Pathology Department. The chief aim of the survey was to reach as many people as possible. This was done chiefly by working through agricultural high school instructors, superintendents of schools and county agents, and also by means of publicity through newspapers and schools. It is needless to say that we received excellent co-operation from both the press and parties above named.

Between 400 and 450 gardens and fields were inspected and several thousand bushels of potatoes were inspected in the markets, warehouses and cars. Most of the inspection was carried on in the vicinity of the Twin Cities and mining regions of the state.

All county agents were first notified to be on the lookout. Sixty-five hundred poster-like cards were distributed to schools of Minnesota. To county agents, markets and others over thirty-five hundred of the cards were distributed making a total of over 10,000 cards.

Three hundred and twenty-five letters were sent to schools containing a prize offer together with a five hundred-word discussion of the disease. County agents were notified of the fifteen-dollar prize offer; some were sent articles of general discussions.

Twenty-six local newspaper articles were written up and published, and almost every paper in the state was reached through the Farm Press News, and notified of the danger of the Potato Wart and also of the prize offer.

Through the plant pathology division a reward of fifteen dollars was offered to the first boy or girl who reported the disease in Minnesota. This prize offer as already stated was published widely and a large number of schools were directly notified. As a result of this prize offer, specimens which were supposed to be affected with Potato Wart have been received from various parts of the state as illustrated herewith.

No evidence of Potato Wart was found, but this does not mean that the disease is not present; as it is impossible to reach everybody in a survey of one year. If all the people can be warned in regard to the seriousness of the disease so they may be on the lookout for it, it may be prevented from spreading. This will be much easier than trying to control the disease after it gets a foothold.

We should keep in mind the national importance of the potato crop and also the seriousness and destructiveness of the Potato Wart. Specialists of the United States Department of Agriculture say that if the disease should spread to commercial plantings it would cost the potato growers millions of dollars annually. If we keep these facts in mind the importance of being on the watch for this dangerous disease is obvious.

All suspicious specimens should be sent to county agents or Plant Pathology Department, University Farm, St. Paul, Minnesota.



FIG. 4. SPECIMENS SENT IN BY CHILDREN

The above specimens were sent in principally during October, 1919, suspected of being affected with wart. These tubers were affected as follows:

Common scab only	30
Black scurf and scab	6
Scab and secondary rot	8
Scab and wire worm injury, etc.	20
"Knobs" and scab	10
Knobs only (see upper tuber)	2
Beets with common scab	2
Rutabagas and turnips with club root	3
(Observe resemblance to wart disease)	
Total specimens (exclusive of portions of potatoes)	81

POTATO WARTS

are *not* knobs on potatoes; they *are* spongy outgrowths, looking something like a small cauliflowets.

LOOK OUT FOR THEM ! ! !

